Abstract: On July 27, 1994, a tractor cargo-tank semitrailer loaded with 9,200 gallons of propane (a liquefied petroleum gas) and traveling east on Interstate 287 in White Plains, New York, drifted across the left lane onto the left shoulder and struck the guardrail. The tank hit a column of the Grant Avenue overpass. The tractor and the semitrailer separated, and the front head of the tank fractured, releasing the propane, which vaporized into gas and ignited. The tank was propelled northward about 300 feet, landing on a frame house and engulfing it in flames. The driver was killed, 23 people were injured, and an area with a radius of approximately 400 feet was engulfed by fire.

The safety issues discussed in this report are truckdriver fatigue, carrier's oversight of the driver's work/rest cycles, countermeasures for single-vehicle roadway departures, compatibility of highway design and the operating characteristics of heavy vehicles and bridge vulnerability, and cargo tank integrity.

As a result of its investigation, the National Transportation Safety Board issued recommendations to the Federal Highway Administration, the Research and Special Programs Administration, the New York State Department of Transportation, the American Association of State Highway and Transportation Officials, the American Association of Motor Vehicle Administrators, the American Trucking Association, and Paraco Gas Corporation, Inc. The Safety Board also reiterated three recommendations to the Federal Highway Administration.

Information about available publications may be obtained by contacting:

National Transportation Safety Board
Public Inquiries Section, RE-51
490 L'Enfant Plaza, S.W.
Washington, D.C. 20594
(202) 382-6735

Safety Board publications may be purchased, by individual copy or by subscription, from:

National Technical Information Service
5285 Port Royal Road
Springfield, Virginia 22161
(703) 487-4600

PROPANE TRUCK COLLISION WITH BRIDGE COLUMN AND FIRE WHITE PLAINS, NEW YORK JULY 27, 1994

HIGHWAY ACCIDENT REPORT

Adopted: November 14, 1995
Notation 6479A

NATIONAL
TRANSPORTATION
SAFETY BOARD

Washington, DC 20594

CONTENTS

EXECUTIVE SUMMARY vii

INVESTIGATION
The Accident 1
  Introduction 1
  Sequence of Events 1
  Emergency Response 5
Injuries 7
Damage 7
  Vehicle Damage 7
  Highway and Bridge Damage 10
  Other 10
Vehicle 10
  Vehicle Inspection 15
    Tractor 15
    Semitrailer 15
    Tank 16
    Metallurgical Examination 16
Driver 16
  General 16
  Training and Qualifications 18
  Work/Rest Cycle 19
Motor Carrier Information 19
  General 19
  Scheduling Practices 19
  Compensation Policy 20
  Oversight of Driver Work/Rest Cycles 21
  Seatbelt Policy 22
Motor Carrier Oversight 22
Highway Information 24
  Highway Description 24
  Pavement 24
  Traffic Volumes and Speeds 26
  Highway Lighting 26
  Median Barrier 26
  Grant Avenue Overpass 29
  Postaccident Physical Evidence 29
  Relationship of Tiremarks and Sideslope 32
  Accident Statistics 32
    Heavy Trucks 32

SVRD Crashes 33
Truck Versus Automobile Characteristics for Highway Design 33
Hazardous Materials Routing 35
I-287 Reconstruction...35
National Highway System 35
Tests and Research..36
Other Information 37
Fatigue-Related Accident Countermeasures..37
New York Task Force on Fatigue Driving...37
Wake Up Brochure...38
FHWA Studies..38
Rumble Strips 39
New Technology and Ongoing Research...39
Activities in Other Modes..40
Bridge Vulnerability 41

ANALYSIS

Introduction...44
Exclusions..44
The Accident...45
Vehicle's Roadway Departure 45
Vehicle Instability/Rollover..45
Collision with Bridge Column..45
Vaporization of Liquid Propane...47
Ignition and Fire...47
Fifth Wheel Separation 47
Truckdriver's Fatigue..47
Operator Fatigue in Transportation Accidents..49
Truckdriver Fatigue-Related Accidents..49
Motor Carrier's Oversight of Driver's Work/Rest Cycles...50
Method of Compensation...50
Education Regarding Fatigue-Producing Effects
of Sleep Deficit and Irregular or Inverted Sleep Schedules 52
Carrier's Oversight of Hours of Service..53
Highway Design Countermeasures for Fatigue-Related Accidents.......................................54
Compatibility of Heavy Trucks and Highway Design...56
Highway Design Standards...58
Previous Safety Board Recommendations Involving Heavy Vehicles and Barrier Systems ..59
NHS...61
Changes in Truck Design..61
Bridge Vulnerability 62
Risk Assessment 66
Cargo Tank Integrity...66

Survival Factors and Emergency Response....69
Collision....69
Fire....69

CONCLUSIONS....70

PROBABLE CAUSE....71

RECOMMENDATIONS....72

APPENDIXES
Appendix A--Investigation....75
Appendix B--Injury Information....77
Appendix C--Rollover Speed Calculations....79
Appendix D--Summary of Consultant's Findings....81
Appendix E--Detailed Time/Distance Analysis....85
Appendix F--FHWA April 12 Memo to Regional Federal Highway Administrators....87

EXECUTIVE SUMMARY

About 12:30 a.m., on July 27, 1994, a tractor cargo-tank semitrailer loaded with 9,200 gallons of propane (a liquefied petroleum gas) and operated by Suburban Paraco Corporation was traveling east on Interstate 287 in White Plains, New York. The truck drifted across the left lane onto the left shoulder and struck the guardrail; the tank hit a column of the Grant Avenue overpass. The tractor and the semitrailer separated, and the front head of the tank fractured, releasing the propane, which vaporized into gas. The resulting vapor cloud expanded until it found a source of ignition. When it ignited, according to an eyewitness, a fireball rose 200 or 300 feet in the air. The tank was propelled northward about 300 feet and landed on a frame house, engulfing it in flames.

The driver was killed, 23 people were injured, and an area with a radius of approximately 400 feet was engulfed by fire.

The National Transportation Safety Board determines that the probable causes of this accident were the reduction in the alertness of the driver (consistent with falling asleep) caused by his failure to properly schedule and obtain rest, and the failure of Paraco Gas Corporation, Inc., to exercise adequate oversight of its driver's hours of service. Contributing to the accident was the design of the highway geometrics and appurtenances, which did not accommodate an errant heavy vehicle. Contributing to the severity of the accident was the vulnerability of the bridge to collision from high-speed heavy vehicles.

In this accident investigation, the Safety Board identified the following safety issues:

1. Truckdriver fatigue
2. Carrier's oversight of the driver's work/rest cycles
3. Countermeasures for single-vehicle roadway departures (SVRDs)
4. Compatibility of highway design and the operating characteristics of heavy vehicles and bridge vulnerability
5. Cargo tank integrity.

As a result of its investigation, the Safety Board issued five safety recommendations to the Federal Highway Administration, one to the Research and Special Programs Administration, one to the New York State Department of Transportation, one to the American Association of State Highway and Transportation Officials, one to the American Association of Motor Vehicle Administrators, one to the American Trucking Association, and two to Paraco Gas Corporation, Inc. The Safety Board also reiterated three recommendations to the Federal Highway Administration.

INVESTIGATION

The Accident

Introduction -- This report presents results of the National Transportation Safety Board's investigation of the following accident. About 12:30 a.m., on July 27, 1994, a tractor cargo-tank semitrailer[1] loaded with 9,200 gallons of propane (a liquefied petroleum gas) and operated by Suburban Paraco Corporation was traveling east on Interstate 287 in White Plains, New York. The truck drifted across the left lane onto the left shoulder and struck the guardrail;[2] the tank hit a column of the Grant Avenue overpass. The tractor and the semitrailer separated, and the front head[3] of the tank fractured, releasing the propane, which vaporized into gas. The resulting vapor cloud expanded until it found a source of ignition. When it ignited, according to an eyewitness, a fireball rose 200 or 300 feet in the air. The tank was propelled northward about 300 feet and landed on a frame house, engulfing it in flames.

The driver was killed, 23 people were injured, and an area with a radius of approximately 400 feet was engulfed by fire.

Included in the report are sections describing the sequence of events, the accident and fire damage, the emergency response, and the vehicle. The driver's work/rest cycle, the motor carrier's oversight of the driver's work/rest cycle, and the features of the roadway are discussed in detail. In addition, the report includes a discussion of fatigue-related accident countermeasures and bridge vulnerability.

Finally, the report analyzes truckdriver fatigue, the carrier's oversight of the driver's work/rest cycles, countermeasures for single-vehicle roadway departures, the compatibility of highway design and the operating characteristics of heavy vehicles and bridge vulnerability, cargo tank integrity, and the survival factors and emergency response. Previous Safety Board accident investigations, safety studies, and safety recommendations are discussed where appropriate.

Sequence of Events -- On the Sunday before the accident, the truckdriver began his work week by leaving his home about 11:00 p.m. He lived in Selden, New York, and this particular work week, a 3-day one, was to consist of picking up a truck with a sleeper berth in

---

[1]For the purposes of this report, the accident vehicle had two major components: the tractor and the cargo tank semitrailer. *Truck* refers to both components. The hazardous-materials industry refers to the tractor-tank semitrailer combination as a *cargo tank*.

[2]The Safety Board was advised in a July 6, 1995, letter from the New York State Thruway Authority that "the term used for roadside safety rail in New York is guiderail, not guardrail." This report uses the terms guardrail and median barrier.

[3]A tank has two ends, or heads— the front head and the back head.

Smithtown, New York, loading and unloading seven loads of propane in the New York City metropolitan area, resting in the sleeper berth at his discretion, returning the truck by 9:00 a.m.[4] on Wednesday, and returning home. (See figure 1 and table 1.)

Between 1:30 a.m. and 8:15 a.m. on Monday, the driver loaded and unloaded two deliveries. At about 9:00 a.m., while he was on his way to pick up the third load, the truck broke down on I-287 at I-87 in New York because of a drive shaft problem. The driver told a New York State Thruway Authority (NYSTA) maintenance supervisor that around noon, while he was waiting for help, he took a 2-hour nap in the truck. At 1:00 p.m., the truck was towed from the highway to the Ryder repair facility and repaired. Ryder employees observed that he fell asleep for about a 1/2 hour in a Ryder van around 4:45 p.m. At 7:15 p.m., he left the repair facility to complete his third load.

Between 4:54 and 9:00 a.m. on Tuesday, he completed his fourth trip, then called his wife, and told her that he was behind schedule because of the breakdown. By 10:53 p.m., he had delivered loads five and six, loaded the seventh, and left the Hess refinery in Port Redding, New Jersey, for Smithtown, with 9,200 gallons of propane.

At 12:19 a.m. on Wednesday, according to toll records, he crossed the Tappen Zee Bridge, traveling south on I-87/287 (New York State Thruway). He then entered I-287 (Cross Westchester Expressway) eastbound, a six-lane highway, toward White Plains. A witness less than 1/4 mile away said that the truck was traveling approximately 55 to 60 mph in the center lane. The witness stated that the truck "drifted" from the center lane across the left lane and onto the shoulder, striking the median guardrail. He said that he did not see any turn signals or brake lights during this movement.

The front head of the tank hit the west bridge column of the center pier of the Grant Avenue overpass (5.8 miles east of the Tappen Zee Bridge) at a 90-degree angle (consistent with a vehicle rollover). The impact sheared the bridge column, and the superstructure sagged. A large portion of the head separated from the tank, releasing the propane, which vaporized into gas. The resulting vapor cloud expanded until it found a source of ignition. When the propane ignited,[5] according to the witness, a fireball rose 200 or 300 feet in the air. The tank was propelled 300 feet northward across the roadway,[6] up an embankment, and into a

---

[4]The driver's wife stated that he normally finished at 4:00 a.m. on Wednesday. The carrier indicated that on the day of the accident, the truck was expected back by 9:00 a.m. and required to be back by midnight.

[5]Liquid propane is a highly flammable gas with a flashpoint of -156 °F. It has a vapor pressure of about 120 psig at 70 degrees.

[6]The roadway is the traveled way plus the shoulder. The traveled way is the part of the road, exclusive of the shoulder, that the vehicles use.

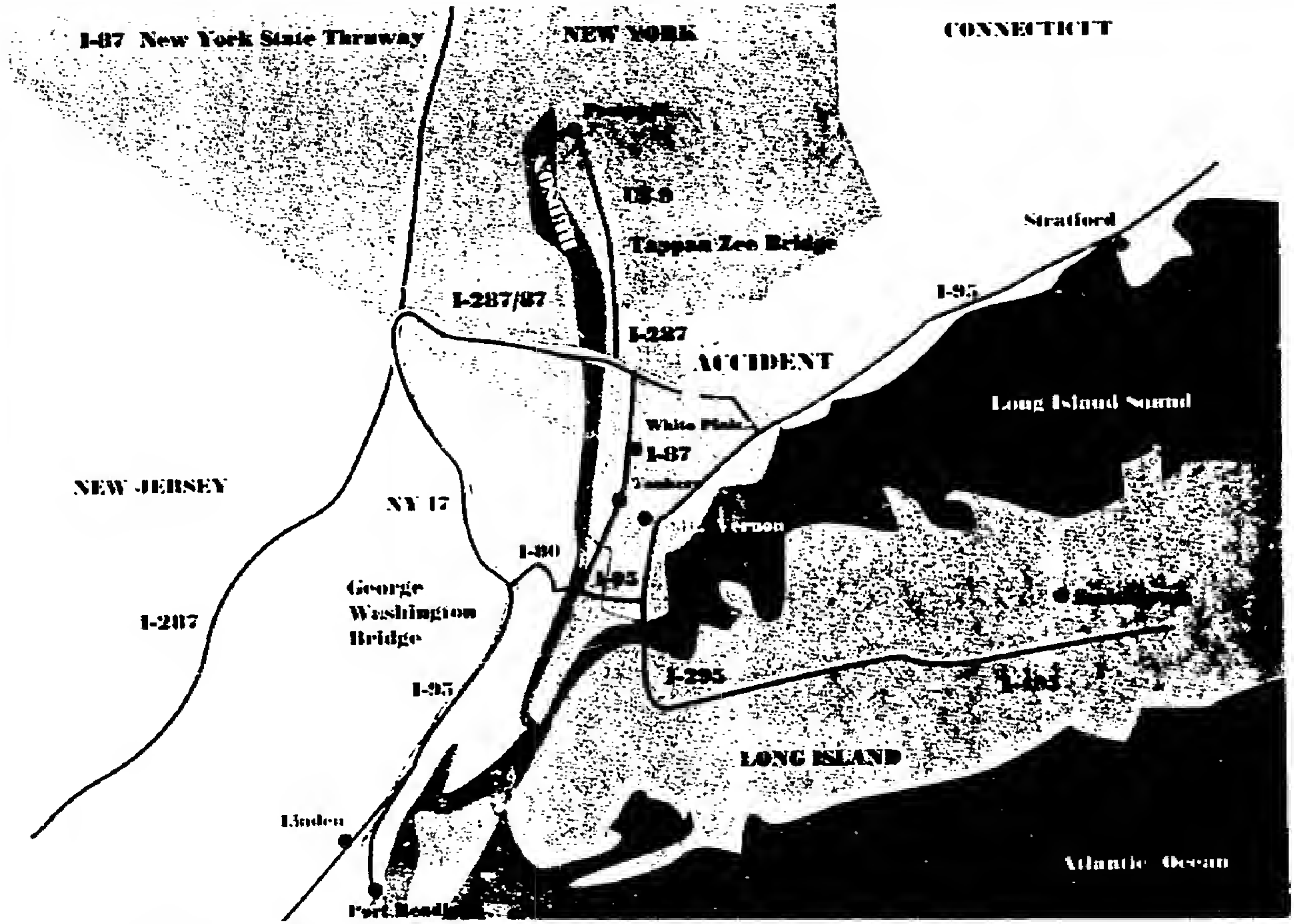


Figure 1. -- Accident driver's routes in the New York metropolitan area (Graphic by Sibyl S. Morgan)

Table 1.—Driver's 72-hour history

Date	Time	Activity	Documented Sleep (hours)
Saturday, July 23	2330-2400	Retired and slept at home in bed	
Sunday, July 24	0700-0730	Awoke from night's sleep	8
	1445-2100	Watched TV at home and napped	
	2130-2230	Slept 1 hour at home in bed	1
	2300	Left for work	
	2330	Left Smithtown (Long Island)	
Monday, July 25	0130	Loading at Bayway refinery (Linden, NJ)	
Load 1	0200	Left Bayway refinery	
	0330	Unloading at Mt. Vernon, NY	
	0430	Left Mt. Vernon	
	0531	Loading at Bayway refinery	
	0552	Left Bayway refinery	
Load 2	0715	Unloading at Peekskill, NY	
	0815	Left Peekskill	
	0900	Breakdown on I-287 at I-87	
	1210	Reported 2 hour nap	2
Breakdown	1300	Towed from highway	
	1420	Arrives at Ryder's garage (Yonkers, NY)	
	1430-1530	Ate sandwich	
	1645-1715	0.5 hour nap in Ryder van	0.5
	1915	Left garage	
	2040	Loading at Hess refinery (Port Reading, NJ)	
Load 3	2128	Left Hess refinery	
	Unknown	Unloaded at Stratford, Connecticut	
Tuesday, July 26	0454	Loading at Bayway refinery	
Load 4	0525	Left Bayway refinery	
	Unknown	Unloaded at Peekskill	
	0900	Telephoned spouse	
	0944	Loading at Hess refinery	
Load 5	1103	Left Hess refinery	
	1300	Unloaded at Peekskill	
	1555	Loaded at Hess refinery	
	1700	Telephoned spouse	
Load 6	1707	Left Hess refinery	
	1940	Unloaded at Mt. Vernon	
	2035	Ate fast food meal	
Load 7	2144	Loading at Hess refinery	
	2253	Left Hess refinery	
Wednesday, July 27	0007	Left Spring Valley Toll Plaza	
	0019	Crossed Tappan Zee Bridge	
	0028	First 911 call (White Plains, NY)	
		Total sleep	11.5

Source: Business records and witnesses

residential neighborhood, where it landed on a frame house, engulfing it in flames. (See figure 2.)

The tractor came to rest in the eastbound lanes, approximately 400 feet east of the bridge. The driver was ejected and died of blunt-trauma injuries.[7] Nineteen residents and four firefighters were injured. The fire destroyed three nearby houses, damaged eight others, and singed a number of trees. The fire also damaged three nearby roadways--Clinton Street, Central Westchester Parkway, and Grant Avenue.

At the time of the accident, the weather[8] was cloudy and the pavement was dry.

Emergency Response -- About 12:28 a.m., the White Plains police department received numerous 911 telephone reports about an "explosion and fire" in the Grant Avenue, Beach Street, and Lennox Avenue area. The first residents to call erroneously stated that an airplane had crashed. A police car arrived at Grant Avenue shortly after the accident. The officers observed a dwelling "fully involved with fire" and immediately notified the fire department and the ambulance service. Another police vehicle arrived on the scene and radioed that house fires were erupting on Grant Avenue, Lennox Avenue, and Clinton Street. The officers told the police dispatcher to send additional firefighters and ambulances.

Other officers heard residents screaming from the roof of 77 Grant Avenue (200 feet south of the bridge). At about 12:40 a.m., an officer using a ladder rescued several adults and children from the roof. Five minutes later (12:45), additional police and fire units arrived and began responding to each burning structure.

Rescuers first alerted and evacuated the occupants of the buildings and then fought the fires. A few minutes later the rescuers established a command post and staging area on Grant Avenue. They established two triage areas, one on each side of I-287; one was on the north side, in front of 103 Clinton Street, and one was on the south side, in front of 80 Grant Avenue. Consolidated Edison Company of New York, Inc., disconnected electricity and natural gas to the residences on Clinton Street and Grant Avenue.

---

[7]According to the Westchester County medical examiner, who conducted the autopsy, the driver's back was burned, but he died as the result of fracture dislocation of atlanto-occipital joint with transection of the medulla-oblongata, skull and rib fractures, and lacerated liver and lungs. No seatbelt loading marks were found on the front of his body.

[8]The Westchester County Airport reported the following weather conditions for 12:25 a.m. on the day of the accident: cloudy skies; visibility, 0.7 miles; fog; and winds from 270° at 5 knots. The airport reported the following conditions for 12:40: partly cloudy; visibility, 0.7 miles; fog; temperature 71 °F; dew point 69 °F; winds from 210° at 6 knots. (The airport, which is in White Plains, is 4 miles from the accident site.)

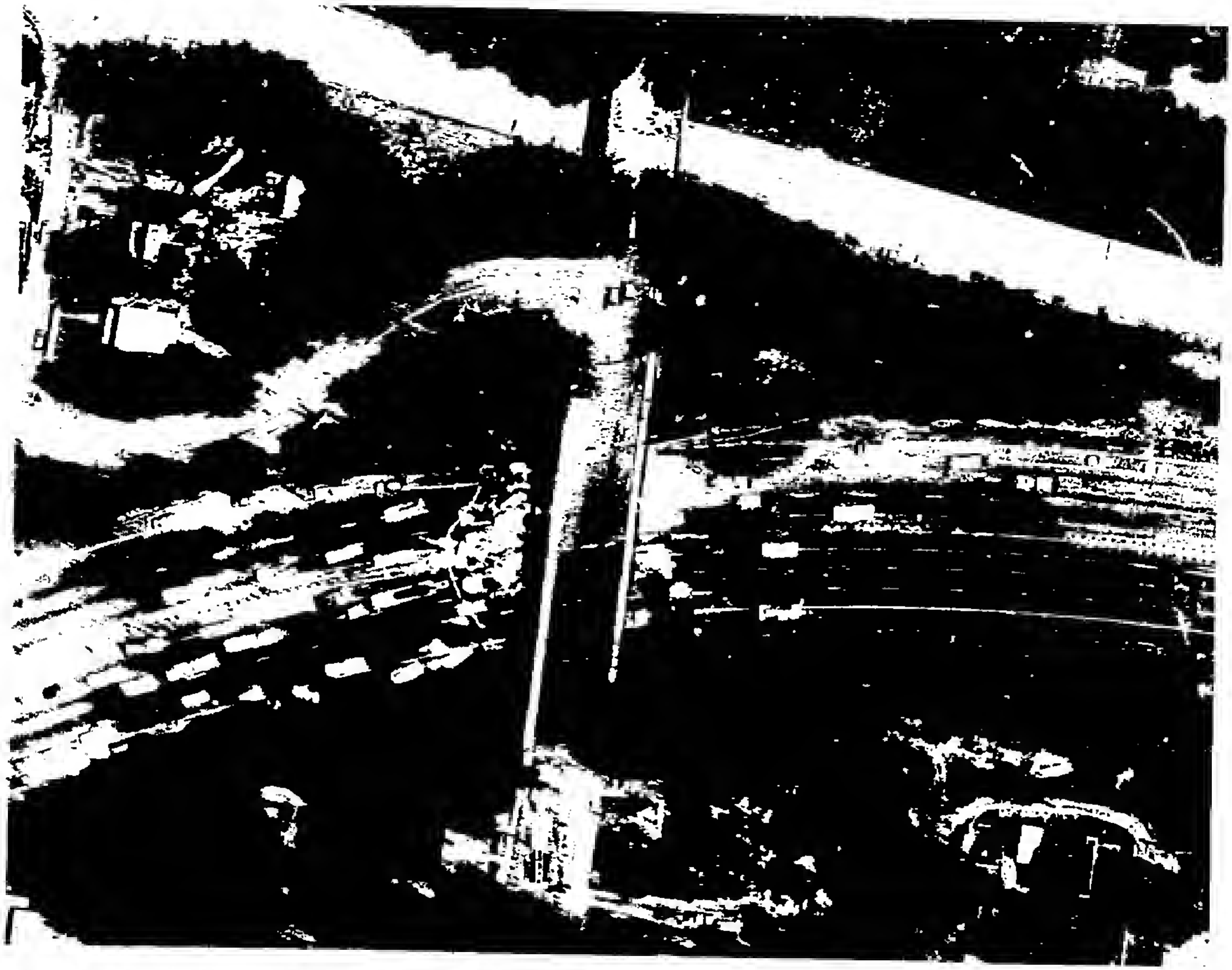


Figure 2. —Aerial view of accident site (Photo by Chas. H. Sells, Inc.)

The injured were transported to three area hospitals (St. Agnes Hospital, Westchester County Medical Center, and White Plains Hospital Center). The emergency was called to an end at 5:45 a.m.

Westchester County holds disaster drills involving local emergency response agencies and hospitals approximately every 6 months. The last drill before the accident, on February 4, had involved a mock bus accident.

Injuries

Sixteen residents were admitted to local hospitals, four with critical burns. Three other residents were treated and released. Four firefighters sustained minor injuries.

Table 2. -- Injuries

Type of Injury	Truckdriver	Residents	Firefighters	Total
Fatal	1	0	0	1
Serious	0	10	0	10
Minor	0	9	4	13
Total	1	19	4	24

Table 2 is based on the injury criteria[9] of the International Civil Aviation Organization, which the Safety Board uses in accident reports for all transportation modes. See appendix B for an injury table based on the Abbreviated Injury Scale of the Association for the Advancement of Automotive Medicine.

Damage

Vehicle Damage -- The tractor body and tires were destroyed by fire. The tractor above the frame rail burned, except for the engine, radiator, fire wall, and fifth wheel. Of the remaining components, only the left side of the front bumper was deformed in a way that could have resulted from a collision. The radiator showed no signs of having been in a collision. (See figures 3 and 4.)

---

[9]Title 49 *Code of Federal Regulations* (CFR) 830.2 defines *fatal injury* as "Any injury which results in death within 30 days of the accident." It defines serious injury as an injury that:

> (1) Requires hospitalization for more than 48 hours, commencing within 7 days from the date the injury was received; (2) results in a fracture of any bone (except simple fractures of fingers, toes, or nose); (3) causes severe hemorrhages, nerve, or tendon damage; (4) involves any internal organ; or (5) involves second or third degree burns, or any burn affecting more than 5 percent of the body surface.

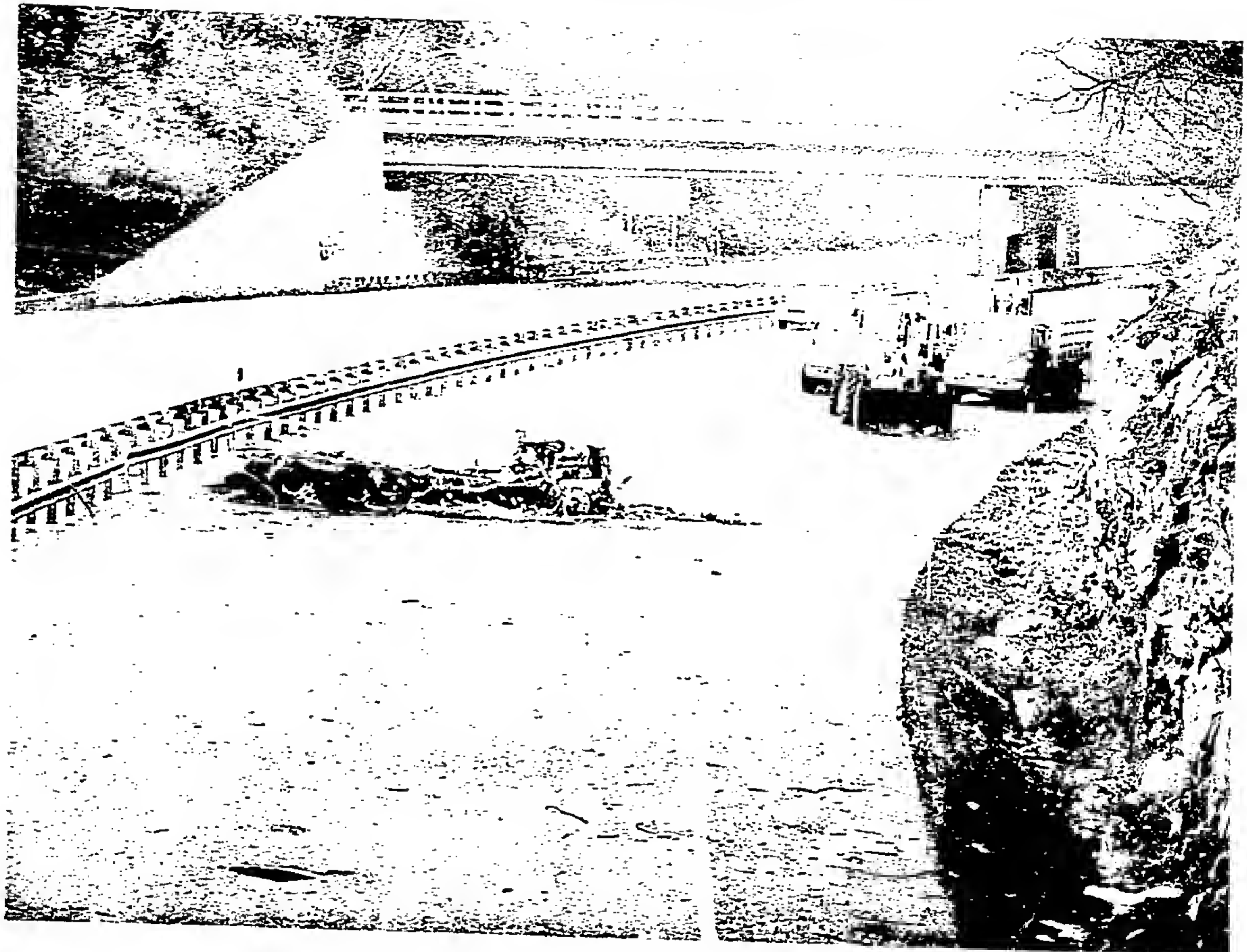


Figure 3. – Final rest position of tractor on I-287 (Photo by Mike Horn)

Figure 4. – Close-up of front of tractor (Photo by Mike Horn)

The exterior of the tank was scorched, except for an area at the lower rear and for the rear manhole cover. A portion of the head was found separated from the tank. The head contained a large cylindrical indentation that was oriented in a horizontal direction (consistent with impact at a 90-degree angle during a vehicle rollover). (See figure 5.) The size of the indentation was consistent with the diameter of the vertical columns of the Grant Avenue overpass. The landing gear, the two-axle assemblies, and the underbody plumbing of the semitrailer were torn away.

Highway and Bridge Damage -- Both the eastbound and westbound median guardrail on the eastbound approach to the bridge was destroyed. The pavement was scorched in several places. The west bridge column was sheared off at the point of impact, causing that portion of the pier cap beam and stringers to sag. (See figure 6.) After the accident, the superstructure was temporarily supported with six steel columns that could take the load should the cap beam sag further. The two interior spans of the southbound spans were later removed. As of November 14, 1995, the bridge was open to a single lane of traffic on Grant Avenue. The cost of cleaning up and temporarily repairing the bridge was $254,000, and the New York State Department of Transportation (NYSDOT) estimated that it would cost $213,000 to repair the bridge and median barrier permanently.

Other -- All lanes of the Cross Westchester Expressway between exit 6 (Broadway) and exit 8 (Westchester Avenue) were closed to traffic for 23 hours. The damage to the residences and parked cars in the neighborhood was estimated to be approximately $1.7 million. (See figures 7 and 8.) The White Plains fire department estimated the cost of the emergency response to be over $100,000.

Vehicle

The conventional tractor had a sleeper berth and was a 1991 Freightliner 3-axle chassis with a diesel engine, 9-speed manual transmission, power steering, and S-cam air brakes. The cargo tank was a DOT Specification MC-331[10] constructed by the Anderson Company, Gainesville, Texas, in January 1991. The tank was manufactured by Trinity Industries, Inc., Dallas, Texas. The cylindrical shell of the tank was constructed of 0.380-inch-thick SA517B steel and had an outside diameter of 84 inches. The heads were concave welded sections, constructed of SA517B steel and had a minimum thickness of 0.250 inch. The tank had a water capacity of 11,500 gallons, was 43 feet and 1 inch long, and had a maximum allowable working pressure of 250 psi at 125 degrees F. The tank was pressure tested to 500 psi.

The truck was 62 feet long and 8 feet wide, and the combined weight of the vehicle and cargo was 80,160 pounds. The tractor had a track width of 73.5 inches, and the semitrailer had

[10] Specification MC 331 is found in 4 CFR 178.337. This section addresses cargo tank motor vehicles used for transportation of compressed gases. It includes sections on fitting and materials specifications and on impact, pressure, and stress testing procedures.

Figure 5. – Front head of cargo tank

Figure 6. – Damaged column of Grant Avenue overpass (Photo by Mike Horn)

Figure 7. – Fire damage at 77-81 Grant Avenue (Photo by Mike Horn)

Figure 8. -- Fire damage of 103 Clinton Street (Photo by Mike Horn)

a track width of 72.5 inches. The tractor was owned by Ryder Truck Rental and leased by Paraco Gas Corporation. The semitrailer was owned by JMR Enterprises, a subsidiary of Paraco Gas Corporation.

The seats for the driver and the passenger had manual lap/shoulder belts with emergency locking retractors that were both vehicle and webbing sensitive. The sleeper berth had manually adjustable restraining belts.

Vehicle Inspection -- After the accident, Safety Board investigators inspected what was left of the truck.

Tractor -- The fire had destroyed the tires, except for the metal parts (plies and bead) and a small section of tread. According to maintenance records, on May 17, 1994, the depth of the tread[11] was between 12/32 and 18/32 of an inch. Because the fire had damaged the brake system, the investigators were not able to determine the brake adjustments by measuring pushrod travel. Maintenance records show that new brake linings had been installed on January 25, 1994, and had last been inspected on June 17, 1994. According to the postaccident measurements, the thickness of the brake lining ranged from 12/32 to 18/32 inch.[12]

Although the steering system was scorched by fire, all linkage was intact. The investigators observed the dismantling and inspecting of the steering box; they did not note any defects. The fifth wheel, a Holland Hitch one, was intact. The right lock jaw was in an open position, while the left lock jaw was in a closed position. Maintenance records indicate the fifth wheel was rebuilt on November 19, 1993. The drive shaft was intact.

The lease agreement with Ryder for the tractor included maintenance. Representatives of both Ryder and the PGC stated that the tractor's speed was governed at 58 mph. The last preventative maintenance inspection had been done about 6 weeks before the accident, on June 17, at which time the odometer reading was 353,461 miles. When the drive shaft was repaired right before the accident, the odometer reading was 364,478 miles.

Semitrailer -- All of the semitrailer tires had rib-type tread design. Although the fire had not damaged the tires and rims, the tires were cut and torn, and the rims were deformed. The depth of the tiretread ranged from 12/32 to 14/32 inch.

---

[11] Section 393.75 of 49 CFR requires a tread groove pattern depth of 4/32 of an inch on the steering axle and 2/32 of an inch on the other axles.

[12]Section 570.59 (c) of 49 CFR requires a minimum brake lining thickness of 1/32 of an inch over the fastener. In addition, the Commercial Vehicle Safety Alliance North American Uniform Out-of-Service Criteria indicates that an out-of-service condition is air brake linings with a thickness of less than 1/4 inch or to wear surface if the lining is so marked, measured at the shoe center for drum brakes.

The semitrailer had tandem dual-wheel axles equipped with S-cam brakes with manual slack adjusters. Brake system damage precluded push rod travel measurements. The postaccident brake lining thickness ranged from 4/16 to 7/16 inches. According to maintenance records, the brakes had last been relined 6 months before the accident, on January 25, and had last been adjusted 3 months before the accident, on April 15.

The semitrailer had a four-spring, tandem-axle suspension system. Both axles and the spring system had separated in the accident. The front spring hangers[13] showed evidence of recent welding and were fractured. Paraco indicated that the pads were welded[14] to the front spring hanger a week or two before the accident. The center and rear spring hangers were deformed, but not fractured.

Tank -- The amount of crush in the front head was about 21 inches. The separation was between the 9 and 2 o'clock position, looking aft (where the 12 o'clock position is defined as the top of the cylinder) along the heat-affected zone of the weld. The fracture then left the circumferential path and extended forward in the cylinder head and returned to the 9 o'clock position. (See figure 9.)

Metallurgical Examination -- The Safety Board's metallurgical inspection consisted of examining the tank, the fourth and fifth axles, the wheel bearing assembly on the right outboard wheel of the fifth axle, and the fifth-wheel kingpin. No preexisting cracks were noted on the parts examined. All fractures examined were typical of over-stress separation.

Driver

General -- The truckdriver, who was 23, had a valid New York State commercial driver's license (CDL); the license had a cargo-tank and hazardous-materials endorsement and an expiration date of September 25, 1995.[15] He had been convicted of a DWI in 1988 and had been involved in two personal injury accidents and two non-moving violations in 1991. These

---

[13]A spring hanger is the attachment used to connect a spring in the suspension system of the truck chassis.

[14]Paraco said the welding was done by S&D Spring and Wheel Alignment Company, Inc., of Ronkonkoma, New York.

[15]Prior to the 1992 requirement for the CDL license, he had possessed a valid New York Class One Commercial Drivers License that permitted him to operate articulated vehicles, including HAZMAT tank trucks weighing more than 26,000 pounds. On December 21, 1990, he passed a CDL road test. On September 23, 1991, he took the CDL written examination at a testing site. He failed three of the seven sections ("Combination Vehicles," "Passenger Vehicles," and "Doubles/Triples"). He passed the Core questions, "Air Brakes," "HAZMAT," and "Tank Truck." The score did not qualify him for a CDL with a combination vehicle endorsement. He asked to be retested. On October 25, 1991, he passed the previously failed sections and was issued a Class "A" CDL with HAZMAT, tank, passenger, and doubles/triples endorsements.

Figure 9. – Front and rear views of tank at rest at 103 Clinton Street
(top photo by Mike Horn; bottom photo by Chas. H. Sells, Inc.)

occurred in a passenger vehicle. In 1993, while driving a truck owned by JMR Enterprises, Limited, he ran a stop light and hit a passenger vehicle. There were no injuries.

On August 4, 1993, the driver, then driving for another employer, had obtained a Medical Examination Certificate, which was still valid when the accident occurred. He was employed by Suburban Paraco Corporation from November 1992 to August 1993 and then rehired in January 1994. His wife indicated that he was in excellent health, did not smoke or abuse alcohol, and did not use any type of drugs or medication.

The Office of the Medical Examiner, Valhalla, New York, and the Center for Human Toxicology, Salt Lake City, Utah, examined the toxicological specimens and did not find any evidence of alcohol or other drugs.

Training and Qualifications -- The driver stated on his employment application that he had had 300 hours of commercial driver training. His personnel file did not contain a written record of preemployment verification. According to the requirements for the CDL tank vehicle and hazardous-materials endorsement,[16] the applicant must demonstrate knowledge of such areas as (1) the effects of road grade and curvature on motor vehicle handling with filled, half-filled, and empty tanks; and (2) hazardous-materials regulations, including placarding requirements. There are no special training or length-of-service requirements.

The 1992 New York State Commercial Driver's Manual states:

> Fatigue (being tired) and lack of alertness are bigger problems at night. The body's need for sleep is beyond a person's control. Most people are less alert at night, especially after midnight. This is particularly true if you have been driving for a long time. Drivers may not see hazards as soon or react as quickly, so the chance of a crash is greater. If you are sleepy, the only safe cure is to get off the road and get some sleep. If you don't, you risk your life and the lives of others.

and

> Your body gets used to sleeping during certain hours. If you are driving during those hours, you will be less alert. If possible, try to schedule trips for hours you are normally awake. Many heavy motor vehicle accidents occur between midnight and 6 a.m. Tired drivers can easily fall asleep at those hours. Trying to push on and finish a long trip at these times can be very dangerous.[17]

---

[16] See 49 CFR 383.119 and 383.121.

[17] New York State Commercial Driver's Manual, New York State Department of Motor Vehicles, October 1992, pp. 2-27 and 2-45.

Work/Rest Cycle -- The driver reversed his work/rest patterns every few days. During the 4 days[18] of the week when he was off duty, he, according to his wife, slept at night, as his family did. Then, during the 3 days[19] that he was on duty, he drove at night to avoid the heavier daytime traffic, thus avoiding delays and longer en-route times. His wife said that he liked the schedule and that he had said "he usually slept 5 to 6 hours each night at work." She said that he usually returned to Paraco Suburban Corporation facility in Smithtown between midnight and 4:00 a.m. on Wednesday mornings.

Motor Carrier Information

General -- Paraco Gas Corporation (PGC) is the parent company of JMR Enterprises Limited, Suburban Paraco Corporation, Paraco Gas of New York Inc.,[20] Patsems Inc., Paraco Security, Optional Fuel Systems, Inc., Paraco Credit Corporation, and Paraco Gas of Connecticut, Inc. The PGC was incorporated in New York State in 1968 and services the New York, New Jersey, and Connecticut metropolitan area with propane gas and welding supplies. The PGC has no Interstate Commerce Commission or New York State operating authority; the company is not required to have such authority because it picks up and delivers to its own facilities or delivers bulk from the refinery to the customer.

The PGC employs approximately 120 full-time employees and 5 part-time employees. The company leases 2 tractors, 20 single-unit propane-tank and/or flatbed trucks, and 13 single-unit service trucks; it owns 2 cargo tanks (including the accident one) and 5 flatbed semitrailers. It has offices in Smithtown, Mt. Vernon, and Peekskill, New York, with corporate offices in Purchase, New York. All of the offices except those in Purchase have propane bulk tank storage. The two cargo tanks pick up bulk propane at refinery and pipeline locations in Port Reading, and Linden, New Jersey, and in Selkirk, New York, and deliver them to the bulk tank storage locations. The residential and commercial distribution of the propane is done by smaller, single-unit straight-body propane trucks.

Scheduling Practices -- The company employed four drivers to deliver propane to bulk tank storage locations. The four drivers shared two trucks; one tractor, the accident one, was equipped with a sleeper berth; the other tractor was not. Previously, each truck was driven

---

[18]Thursday, Friday, Saturday, Sunday.

[19]Monday, Tuesday, Wednesday.

[20]Formally known as Paraco Fuel Corporation.

two shifts a day, and each driver returned to the home terminal on a daily basis. In May, 2 months before the accident, the dispatching practices were changed.[21]

Under the new system, the two drivers who shared the tractor without a sleeper berth continued as before. The other two drivers, however, the two who shared the tractor with a sleeper berth, switched to working 3 days a week. The accident driver worked Monday, Tuesday, and Wednesday; and the other driver worked Thursday, Friday, and Saturday. The dispatcher received pickup and delivery information from corporate headquarters during the week and assigned pickups and deliveries the day before the driver was scheduled to work. If the driver finished his assigned trips before the last day of the shift, he could return to the Smithtown terminal, his work week completed. (The accident driver was normally expected to return on Wednesdays by 9:00 a.m.) According to the PGC, in the week of the accident, he was not required to return the vehicle until 12:00 a.m. on Thursday, when the next driver was scheduled to start.

The dispatcher told Safety Board investigators that the system was changed so that the drivers could manage their pickups and deliveries around the heavy traffic in the tri-State area.

Compensation Policy -- A driver was paid a flat rate[22] for each trip (pickup and delivery) he completed. He was also paid $15.00 an hour if his truck became disabled or if he spent excessive time waiting to be loaded or unloaded at refineries or storage areas. According to the vice president of finance, when a driver was on the road, the PGC required him to call in regularly to report his location, the traffic conditions, and his position on the refinery waiting-to-be-loaded list. If the truck broke down, Ryder, under a service contract to the PGC, repaired it.

In addition, the PGC had a policy of, "when necessary,"[23] rescheduling or reducing the number of trips a driver was required to make if his vehicle had broken down. No criteria or procedures were documented. The driver was permitted to continue his deliveries after a mechanical breakdown of approximately 10 hours.

---

[21]The PGC hired the dispatcher as a driver in February 1994, and in May 1994 gave him the additional duty of being the dispatcher, or wholesale transport supervisor. In May 1994, he changed the dispatch and scheduling system.

[22]This rate varied from $100 to $160, depending on the length of the trip.

[23]In a June 30, 1995, letter to the Safety Board, the PGC stated that its policy was to reschedule or reduce the number of trips "when necessary." According to the PGC, the policy was followed on the day of the accident, and the driver was permitted to continue his deliveries after a breakdown of approximately 10 hours, because the breakdown did not necessitate rescheduling or reducing the number of trips he was required to complete. According to the company, the number of trips the driver had been assigned could still have been completed within the hours-of-service limitations, and the truck could have been returned by the required time.

Oversight of Driver Work/Rest Cycles -- According to the PGC safety director, the drivers could schedule their own work/rest cycles because the accident truck had a sleeper berth. The dispatcher stated that the drivers liked the new dispatch system because it allowed them more flexibility in matching their rest periods to traffic conditions.

Under the old dispatch system the drivers were not required to keep records of their duty status in daily log books. They did not have to keep records because they were out for fewer than 12 hours and made their deliveries within 100 air miles of their facility. However, under the new system, the drivers were out for 3 days at a time and, therefore, were required by the Federal Motor Carrier Safety Regulations (FMCSR) to keep records of duty status.

According to the PGC's safety manual, the *Propane Transport Procedures*, the top company management was ultimately responsible for the company's safety program. The operating management was responsible for implementing and monitoring safety programs and for ensuring compliance with all local, State, and Federal safety rules and regulations. The safety department was responsible for, among other things, monitoring safety performance and compliance with safety programs.

According to the safety manual, the transport supervisor[24] was responsible for reviewing bills of lading and log reports. However, he indicated that he was not responsible for supervising bulk propane drivers for possible hours-of-service regulations violations and had no knowledge of any of these violations by the drivers.

The vice president of finance and the safety director told Safety Board investigators that the "PGC had three levels of oversight to ensure the driver was picking up and delivering his assigned loads." The first level was the dispatcher. When the driver completed his assigned trips, he was not paid until he had given the dispatcher documentation for each trip. The documentation consisted of three items: driver's logs, PGC (JMR Enterprises Limited) bill-of-lading sheets, and refinery pickup tickets. These documents indicated the time the loads were picked up and delivered, the travel time between pickup and dropoff points, and the driver's work/rest cycle.

The second level was the manager of the Smithtown terminal, who reviewed the documents again. The third level was the purchasing manager at corporate headquarters, who reviewed the documents once again. He compared the loads picked up to the loads delivered and noted any time earned while the driver was being paid under the hourly agreement for downtime.

---

[24]According to the PGC safety director, the terms *transport supervisor*, *wholesale transport supervisor*, and *dispatcher* refer to the same position.

Seatbelt Policy -- According to the PGC, it did not have a written policy regarding seatbelt use. The company indicated that it did have a written policy that all drivers obey the applicable *CFR* requirements and State laws. The company also indicated that when the accident driver took the preemployment written examination, he answered the question regarding seatbelt use correctly.

The Office of Motor Carriers (OMC), which is a part of the Federal Highway Administration (FHWA), has the following requirements for seatbelt use in 49 *CFR* 392.16 "Use of Seat Belts":

> A motor vehicle which has a seat belt assembly installed at the driver's seat shall not be driven unless the driver has properly restrained himself with the seatbelt assembly.

Title 17 of the New York State Transportation Law (Section 820.6) required drivers of commercial vehicles (both interstate and intrastate) to use seatbelts.

Motor Carrier Oversight

After the accident, the OMC investigators examined the accident driver's pickup and delivery schedule for the week of the accident. Using the 72-hour history (developed for this report) and the computer program P.C. Miler (a mileage program developed for the OMC), the investigators reconstructed the assigned trips. They computed the distance between pickup and delivery locations. (They assumed that the driver had been traveling at 55 mph; the computer program does not take into account traffic or travel conditions or rush-hour hazardous-materials restrictions in New York City.) The investigators allowed for the time the driver had spent loading, unloading, and taking required rest/sleep periods. The OMC concluded that had the driver gone on duty at 11:30 p.m. on Sunday and gone off duty at 4:00 p.m. Wednesday, the assigned trips could be completed within the hours-of-service regulations. The OMC stated in a June 30, 1995, fax that "although this reconstruction will show how the assignment could have been completed within the legal time constraints, OMC has proven that it was not being performed in that manner."

The OMC also conducted a compliance review[25] of Suburban Paraco Corporation. The OMC examined 122 records of duty status made by three of the drivers between May 1 and

[25]49 CFR Part 385.3 "Definitions:"

(1) *Compliance review* means an on-site examination of motor carrier operations, such as driver's hours of service, maintenance and inspection, driver qualification, commercial drivers license requirements, financial responsibility, accidents, hazardous materials, and other safety and transportation records to determine whether a motor carrier meets the safety fitness standard. A compliance review may be conducted in response to a request to change a safety rating, to investigate potential violations of safety regulations by motor carriers, or to investigate

July 19, 1994. It found that in the 80 days the two drivers had shared the accident truck, they had made 37 false entries, of which 25 had been made by the accident driver. For example, on several occasions, one of the two drivers had listed himself as being off duty for a period of 24 to 48 hours, periods during which he was actually on duty and making bulk propane pickups at several refineries. The OMC gave the Suburban Paraco Corporation a conditional rating,[26] noting numerous hours-of-service violations.

Suburban Paraco Corporation requested that the OMC audit the days after the accident. In May 1995, the OMC conducted a compliance review and issued a rating of satisfactory.

Before the accident, the OMC was aware of several, but not all, of the PGC's sub-companies. The OMC had conducted oversight inspections and assigned the resulting safety ratings shown in table 3.

Table 3. -- Paraco Gas Corporation safety ratings

Date	Sub-Company Name	Type of Review	Rating
May 1984	Paraco Fuel Corp.[27]	Safety Management Audit MCS-32	Conditional
April 1985	Paraco Fuel Corp.	Safety Management Audit MCS-32	Conditional
April 1987	Paraco Fuel Corp.	Compliance Review MCS-151	Satisfactory
June 1992	Paraco Fuel Corp.	Cargo tank facility audit MCS-151	Audit does not require rating.[28] The company paid a civil forfeiture of $2436.00
September 1994 (Postaccident)	Paraco Gas of New York, Inc.	Compliance Review MCS-151	Satisfactory
September 1994 (Postaccident)	Suburban Paraco Corp.	Compliance Review MCS-151	Conditional, numerous hours-of-service violations
September 1994 (Postaccident)	Patsems Inc. D/B/A Paraco Gas	Compliance Review MCS-151	Satisfactory
May 1995 (Postaccident Request)	Suburban Paraco Corp.	Compliance Review MCS -151	Satisfactory
June 1995 (Postaccident Request)	Suburban Paraco Corp.	Cargo tank facility audit MCS-151	Audit does not require rating

complaints or other evidence of safety violations. The compliance review may result in the initiation of an enforcement action.

[26]A conditional rating as defined by FMCSR 385.3 means a motor carrier does not have adequate safety management controls in place to ensure compliance with the safety fitness standard that could result in the occurrences listed in section 385.5 (a) through (h). FMCSR 385.5 lists (g) The use of fatigued drivers.

[27]In December 1993, Paraco Fuel Corporation changed its name to Paraco Gas of New York, Inc.

[28]Numerous violations relating to the testing and inspection of the company's own cargo trucks were documented.

Highway Information

The accident occurred in the eastbound lanes of the Cross Westchester Expressway (I-287) at the Grant Avenue overpass. The six-lane limited-access highway is a major east-west transportation corridor and northern bypass of New York City. It links I-87 (New York State Thruway) to I-95 (New England Thruway). (See figure 10.)

This section of I-287 was designed and built in the late 1950s by the New York State Department of Public Works (now the NYSDOT) with Federal aid. In 1990, the New York State Thruway Authority bought I-287 from the State. On April 1, 1991, the NYSTA assumed responsibility for operating and maintaining the highway and most of the ramps. The NYSDOT retained the responsibility for the design, construction, and maintenance of the bridges. It also retained the responsibility for the design and construction or reconstruction of the pavement.

Highway Description -- The accident occurred on a 1,550-foot-radius (centerline radius) curve to the right on a 2.26-percent downgrade. (See figure 11.) The curve was 2,246 feet long and had 250-foot-long spiral transitions at each end. The centerline of the Grant Avenue bridge was 1,750 feet from the beginning of the curve. The bank or superelevation for the curve was +0.06 (percent). At the accident site the left shoulder slope was approximately -0.02 and the embankment foreslope approximately -0.16.

The highway had three lanes in each direction, and each lane was 12 feet wide. The right shoulders were 10 feet wide. The median consisted of 5-foot-wide left shoulders that were separated by a 10-foot-wide paved drainage ditch with a W-beam guardrail. Each lane line was 10 feet long and separated from the next by 25 feet. The left edge lines were 7.5 inches wide. The NYSTA stripes its highways with 6-inch-wide edge and lane lines. The reflectorized white lane lines and yellow and white edge lines were in good condition and met the requirements about width and space specified in the *Manual on Uniform Traffic Control Devices (MUTCD)*.[29]

Pavement -- In 1991, the roadway was paved with a type 6 bituminous plant mixture that the NYSDOT considered a high friction mixture. Two days after the accident, the NYSTA performed friction tests, on the westbound left lane and foreslope. The dry coefficient of

[29] The MUTCD is approved by the FHWA as the standard for all streets and highways in accordance with Title 23, U.S. Code, Sections 109 (b), 109 (d), and 402 (a) and 23 CFR 1204.4.

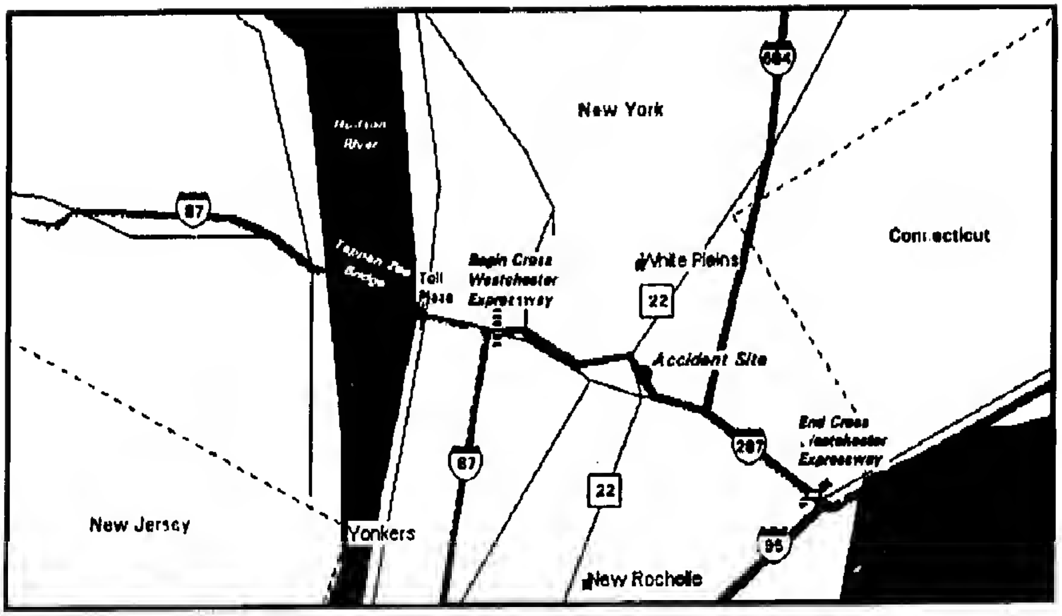


Figure 10.-- I-287/Cross Westchester Expressway

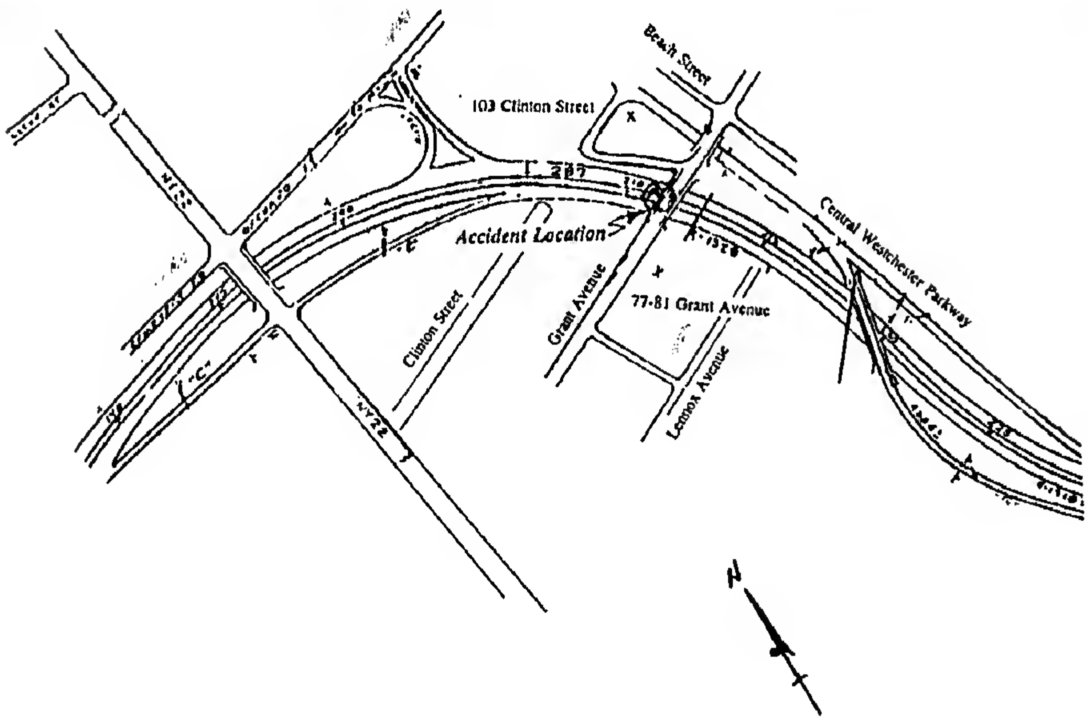


Figure 11. – Plan view of accident site

friction for the left lane averaged 0.73.[30] The repaving raised the shoulder 3 1/2 inches above the foreslope. Rumble strips[31] were not installed at the accident location.

Traffic Volumes and Speeds -- The average daily traffic (ADT) was 105,000 vehicles. On the day of the accident, 54,132 vehicles passed through the Tappan Zee Bridge eastbound toll barrier. Of these vehicles, 3,490 were commercial, and 1,702 were tractor-semitrailers with five or more axles. The number of vehicles carrying hazardous materials, or cargo tanks, was not available.

Hourly traffic counts[32] for three Wednesdays in June and one in July 1994 indicate that between midnight and 1:00 a.m. the eastbound average was 67 vehicles. The eastbound ADT for the same Wednesdays was 74,996, and the ADT for both directions was 144,880.

The speed limit was 55 mph. The highway design speed was 60 mph.

Highway Lighting --I-287 had no highway lighting between the Tappen Zee Bridge and the New England Thruway. The American Association of State Highway and Transportation Officials (AASHTO) guidelines and the FHWA standards do not require highway lighting.

Median Barrier -- The median barrier at the accident site was a "heavy post blocked-out W-beam median barrier," AASHTO designation G4(1S). The W-beam was 12 1\2 inches wide and was mounted (blocked-out) on a 6-inch-deep beam connected to a 6-inch-deep post. The post was 5 1/2 feet long, and the top of the rail was 27 inches above the ground. A single post supported the W-beam section for both eastbound and westbound traffic on the horizontal curve west of the Grant Avenue bridge, except where the section separated to go around the center pier. The accident occurred in the approach area, which had separate posts for the W-beam sections.

The original construction did not include a median guardrail. The NYSDOT box beam guardrail was added at a later date. (See figure 12-A.) In 1991 when the roadway was repaved, the median barrier was changed to the heavy post blocked-out W-beam barrier and was moved to the backslope and gradually flared toward the foreslope. (See figure 12-B.) It was connected to a 32-inch-high concrete barrier adjacent to the center bridge pier. (See figure 12-C.)

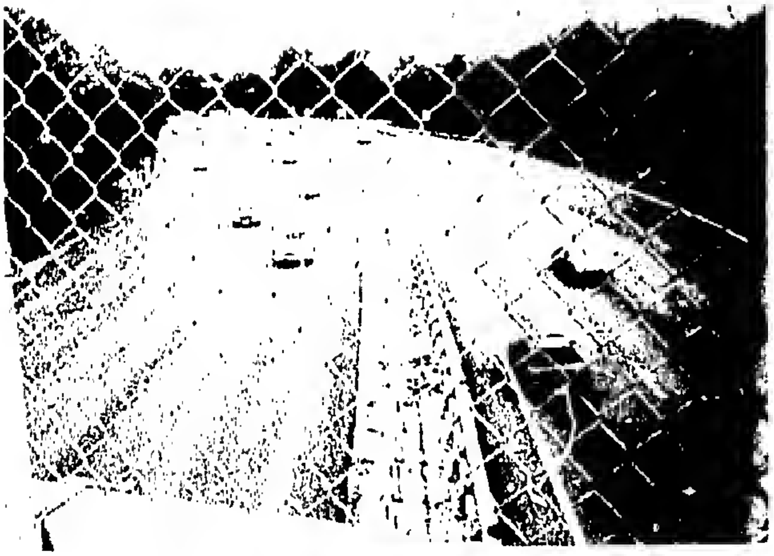
---

[30]Considered high-quality pavement by the American Association of State Highway and Transportation Officials (AASHTO). See AASHTO, *A Policy on Geometric Design of Highways and Streets*, 1994, p. 122.

[31]Rumble strips are grooved patterns that are rolled, formed, or milled into the shoulder pavement perpendicular to the roadway edge line. These grooves create vibration and a rumbling sound when vehicles ride over them.

[32]NYSDOT traffic data from a continuous count station located 1.8 miles west of the Grant Avenue overpass. There is one on-ramp and one off-ramp between the count station and the accident site.

A -- Looking west from Grant Avenue overpass at box beam guardrail



B -- Looking west from Grant Avenue overpass at strong post block-out guardrail

C -- Attachment of W-beam guardrail to concrete barrier

Figure 12.

Although the project design was within AASHTO specifications,[33] the project was built without Federal funds or FHWA oversight.

The blocked-out W-beam (strong post) barrier system in place at the time of the accident was a standard design that had been used by the NYSDOT since 1979. After the accident, the guardrail was replaced with another guardrail of the same design. This system is the most common barrier system in use today, but it was designed primarily to protect passenger cars by redirecting them from roadside obstacles. It is classified as an operational semi-rigid system by the AASHTO *Roadside Design Guide*, which means that it has demonstrated satisfactory field performance in terms of construction and has been successfully crash tested for automobiles.[34] In crash tests, this barrier was marginally successful in redirecting two pickup trucks weighing 3,260 and 4,179 pounds, respectively.

Only rigid barriers have been generally successful in redirecting large vehicles. The commonly used 32-inch-high New Jersey barrier has successfully, during moderate impacts, redirected buses weighing up to 40,000 pounds. A barrier with greater performance capability is required for heavy tractor-semitrailers. A 42-inch-high New Jersey shape barrier has successfully redirected an 80,000-pound tractor-semitrailer at 15 degrees and 52 mph.[35]

The National Cooperative Highway Research Program[36] (NCHRP) Report 230, *Recommended Procedures for the Safety Performance Evaluation of Highway Safety Appurtenances*, published in 1980, has provided a minimum crash-test matrix for most roadside hardware. The matrix is based on the results of tests of passenger cars that weigh between 1,800 and 4,400 pounds. In 1987, AASHTO recognized that Report 230 needed updating for many reasons, including significant changes in the vehicle fleet. The result was NCHRP Report 350, which was published in 1993.

NCHRP Report 350, *Recommended Procedures for the Safety Performance Evaluation of Highway Features*, includes supplemental test vehicles, including tractor-semitrailers weighing 80,000 pounds. No warrants or specifications have yet been established for these vehicles; NCHRP Project 22-12, *Guidelines for the Selection, Installation, and Maintenance of Highway-Safety Features*, is expected to develop them. The research problem statement for Project 22-12 specifies that, among other things, the project will address the selection of

---

[33]AASHTO, *A Policy on Geometric Design of Highways and Streets*, Washington, D.C., 1990.

[34]AASHTO *Roadside Design Guide*, Washington, D. C., 1989, chapter 5, p. 10.

[35] AASHTO *Roadside Design Guide*, Washington, D. C., 1989, chapter 5, p. 14.

[36]The NCHRP is administered by the Transportation Research Board, sponsored by participating members of AASHTO in cooperation with the FHWA, and is funded by participating State highway and transportation agencies.

appropriate guardrail for the characteristics of the site and the upgrading of existing highway-safety features. The FHWA expects the study to be completed in 1997.

In 1993, the FHWA required that Report 350 be used for "guidance in determining the acceptability of roadside barriers and other safety appurtenances for use on National Highway System (NHS) projects..." (See the discussion of the National Highway System.)

Grant Avenue Overpass -- The bridge was a steel girder structure consisting of four simply supported[37] spans of eight girders each and was supported by three piers and two abutments. The reinforced concrete deck was 54 feet wide. The bridge was 232 feet long and formed an angle of 76 degrees with I-287. Each pier consisted of four 3 1/2 foot diameter reinforced concrete columns connected by a reinforced concrete pier cap. The columns were built along a straight line, and each rested on an isolated spread concrete footing. The faces of the 14-foot-2-inch center pier columns were 8 feet from the traveled way. (See figure 13.)

The span over the eastbound lanes was 69 feet long, from center of pier to center of pier. It was fixed on the south pier; the expansion joint was at the center pier. The span over the westbound lanes was 61 feet long; its fixed end was over the center pier, and its expansion end was over the north pier.

Postaccident Physical Evidence -- Safety Board investigators documented 130 feet of tiremarks in the eastbound lanes of I-287. The marks began approximately 200 feet in front of the bridge column in the left lane and continued to the shoulder and foreslope of the drainage ditch. Near the end of the 130 feet, the marks started curving back to the roadway. The marks left the traveled way (across the pavement edge line) and the shoulder at an angle of 5 degrees. (See figure 14.)

Safety Board investigators documented gouge marks and tiremarks in the eastbound lanes beyond the bridge. Two gouge marks were about 57 feet from the destroyed bridge column. One was on the left lane line, and the other was in the center lane. A tiremark started just beyond the gouge marks and crossed the center lane to the right lane and then curved back toward the center lane. Another tiremark began in the center lane and ended just beyond the location of the windshield (155 feet from the destroyed column).

An examination of the damaged guardrail, which had been cut into sections and moved to a NYSTA maintenance facility, revealed tiremarks and blue paint marks that appeared to match the blue paint of the truck. The tractor was white, and the cargo tank was white with blue fenders and undercarriage.

---

[37]A simply supported span is supported at each end by a single unrestraining bearing or support and is designed to be unaffected by stress transmission to or from an adjacent span or structure.

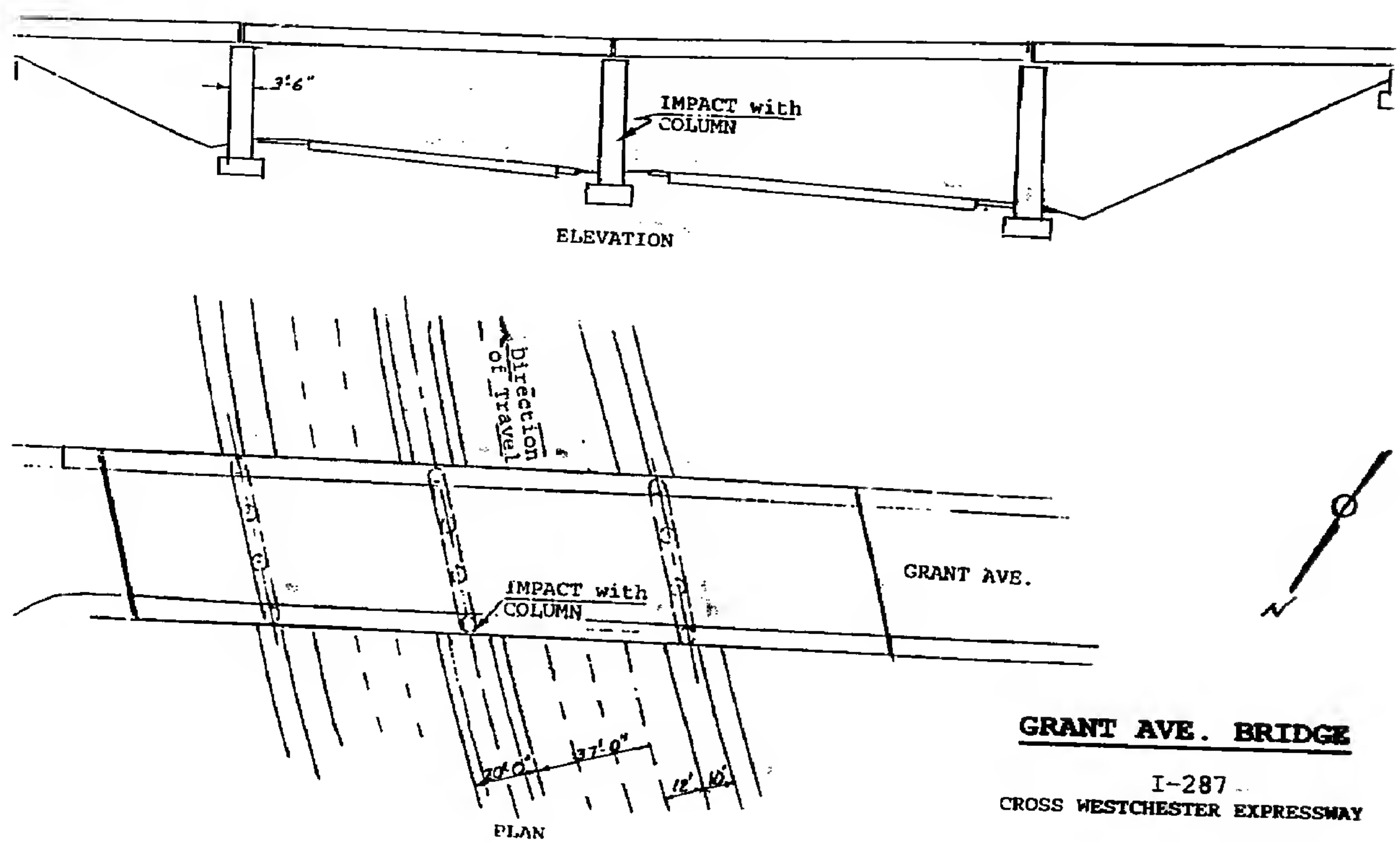


Figure 13.--Schematic of Grant Avenue overpass

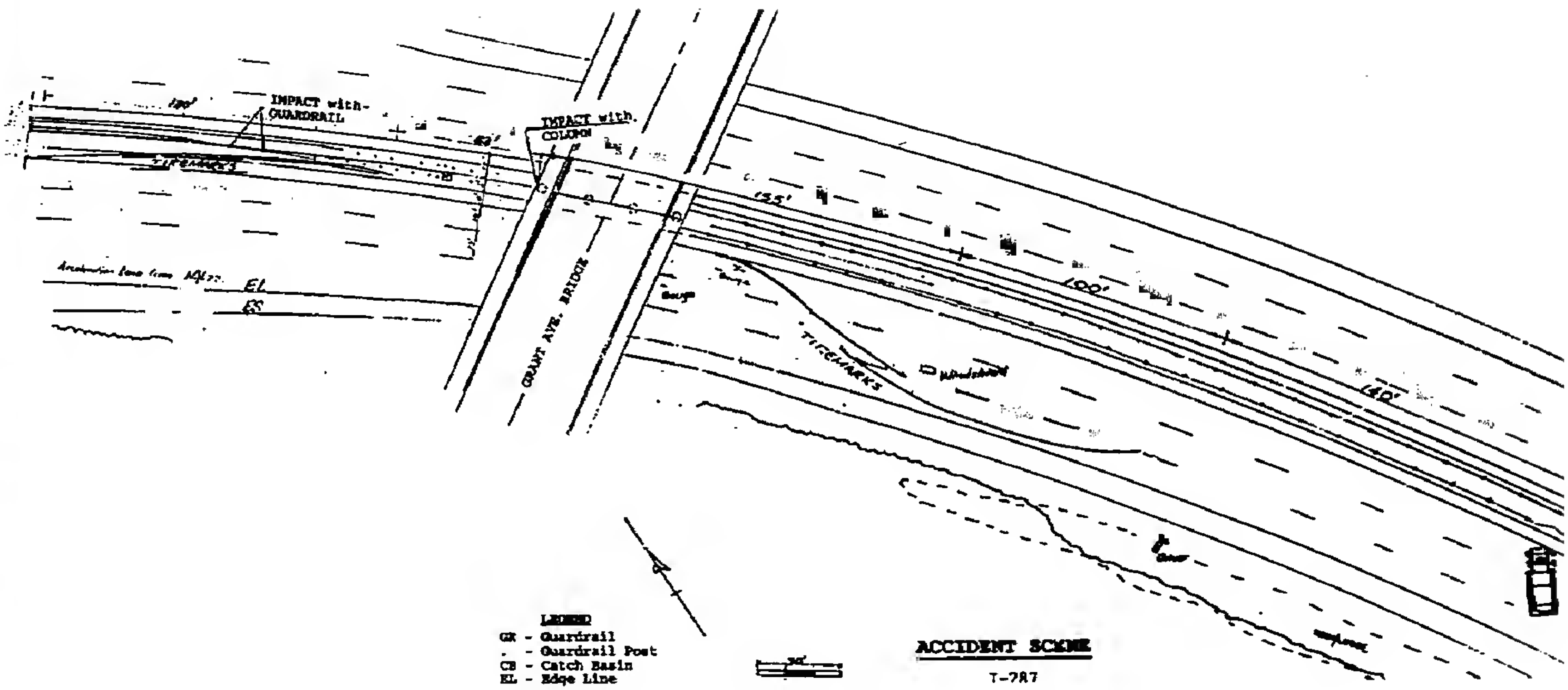


Figure 14.--Accident scene

Several motorists reported that before the accident they had seen a section of tiretread in the eastbound roadway.

Relationship of Tiremarks and Sideslope -- From the point where the first left wheels went off the shoulder (132 feet west of the destroyed column) to the point where the left tiremarks ended (53 feet west of the column), the percent slope between the bottom of the ditch and the top of the edge of shoulder varied from -0.125 and -0.169.

Accident Statistics -- According to the NYSTA, in the vicinity of the accident site, within the limits of the 2,245-foot horizontal curve, there were 23 accidents in 1994, 7 in 1993, and 7 in 1992. Of the 23 accidents in 1994, 11 were in the eastbound direction. Four of the 11 were at night. Three (in addition to this accident) were single-vehicle roadway departures (SVRDs) to the left; none involved a truck. The NYSTA's accident rates for 1994 are summarized in table 4.

Table 4. -- New York State Thruway Authority accident rate comparisons (1994)

Location	Accident Rate per 100 Million Vehicle Miles
Accident site - Eastbound (2,245 foot curve)	62
Cross Westchester Expressway - Eastbound (11 miles)	95
New York Thruway - Both Directions (641 miles)	97

In 1992, 40 percent (12 of 32) of the fatal accidents on the NYSTA "were caused by drivers falling asleep at the wheel."[38] Drivers traveled more than 6 billion miles on the 641-mile system. The NYSTA fatality rate for 1992 was 0.53 deaths per 100 million miles traveled, the lowest rate in the NYSTA's 39-year history. Nationally, the overall fatality rate for all roads in 1992 was 1.8 per 100 million miles traveled, and for the interstate it was below 1.0.

Heavy Trucks -- According to the National Highway Traffic Safety Administration's (NHTSA's) statistics from the Fatal Accident Reporting System data, in 1994, 5,112 people died in large-truck crashes. (NHTSA defines a large truck as one weighing more than 10,000 pounds.) Twenty-four percent of large-truck crashes occur on freeways. Of the 1,234 deaths in large-truck crashes on freeways in 1994, 284 were single-vehicle crashes.

[38] Shafer, John H., "The Decline of Fatigue Related Accidents on the NYS Thruway," *Proceedings of the Highway Safety Forum on Fatigue, Sleep Disorders and Traffic Safety*, Albany, New York, December 1, 1993.

In 1990, heavy trucks[39] accounted for 3 percent of the registered vehicles and 7 percent of the vehicle miles traveled; 11 percent of all fatal crashes involved heavy trucks. Tractor-semitrailers had a higher fatal crash rate (3.9 per hundred million vehicle miles) than either passenger vehicles (2.5) or single-unit trucks (1.8). Tractor-semitrailers traveled 49 percent of their miles on interstates; passenger cars traveled only 23 percent. Tractor-cargo tanks were not separated in this analysis.

SVRD Crashes -- SVRD crashes are often associated with fatigued drivers. The Safety Board examined accident statistics and research in these related areas.

In 1992, 1.2 million SVRD crashes, or 20 percent of all crashes, resulted in 16,000 fatalities, or 36 percent of all traffic fatalities. Based on 1991 General Estimates System data,[40] fatal SVRD crashes occurred most often between midnight and 6:00 a.m. on a weekday. Fatal SVRD crashes were also most likely to occur on highways with speed limits of 55 to 65 mph. In addition, the average tractor-semitrailer could have been expected to be involved in 0.23 SVRD crashes during its operation life. Forty-four percent of fatal tractor-semitrailer SVRD crashes occurred on curves; 22 percent involved rollover. Driver drowsiness was a factor in 15.2 percent of the SVRD crashes of tractor-semitrailers.

The Volpe National Transportation Systems Center, a part of the U.S. Department of Transportation (DOT) Research and Special Programs Administration (RSPA), recently completed a 3-year project that identified causal factors of eight crash types, one of which was the SVRD.[41] The analyses identified relevant precrash circumstances and assessed some mechanisms of intervention. The driver was found to be asleep in 12 percent of the cases in which the vehicle ran off the road.

Truck Versus Automobile Characteristics for Highway Design -- Highways have traditionally been designed to accommodate the limitations of automobiles. Recently highway research has identified the need to design highways to accommodate the limitations of trucks. A 1989 FHWA[42] study states the following:

---

[39]The American National Standards Institute defines a light truck as having a gross vehicle weight rating under 10,000 pounds, a medium truck as having a rating between 10,000 and 26,000 pounds, and a heavy truck as having a rating over 26,000 pounds.

[40]The General Estimates System is a NHTSA accident data system that obtains its data from a nationally representative probability sample selected from all police-reported crashes. The sample includes fatal, personal injury, and property damage crashes.

[41]Mironer, W., Mironer, M., and Fraser, L., *Analysis of Target Crashes and ITS/Countermeasures*, Preprint, Paper No. 95-118, ITS America, 1995 Annual Conference, 1995, Washington, D.C.

[42]*Truck Characteristics for Use in Highway Design and Operation*, FHWA-RD-89-226, 227.

Many highway design and traffic operational criteria are based in part on vehicle characteristics. Most of these criteria are based on automobile characteristics, even though truck characteristics may be more critical.

Rollovers[43] are the principal manifestation of the limited vehicle dynamics/handling capability of heavy trucks. In 1990, the Safety Board published the results of one of its studies of truck crashes.[44] Among the Board's findings were the following facts: in a sample of 186 fatal truck crashes, 55 percent had involved rollover; of all the medium- and heavy-truck crashes in Maryland and Pennsylvania during 1988 through 1990, 9 percent included rollover; occupants of the trucks or other vehicles were killed or injured in 71 percent of the rollover crashes and in 52 percent of the nonrollover crashes.

AASHTO criteria for horizontal curve design do not explicitly consider vehicle rollover thresholds. Automobiles have rollover thresholds as high as 1.2g and, therefore, normally skid sideways before they roll over. Because tractor-semitrailers have higher centers of gravity, they have relatively lower rollover thresholds; historically trucks have been considered to have thresholds of 0.40g. Suspension stiffness, load shifts (both lateral and longitudinal), and other factors may reduce the rollover threshold of tractor-semitrailer. The 1989 FHWA study suggests a rollover threshold of 0.30g is appropriate for the design of highways. However, cargo tanks can have a rollover threshold as low as 0.26g, while some unusually loaded vans may be as low as 0.24g.[45]

Data from the 1989 FHWA study were used to update the 1984 edition of AASHTO's *A Policy on Geometric Design of Highways and Streets* to accommodate the changes made in the maximum allowable dimensions for tractor-semitrailers as well as other developments that have taken place since 1984. The 1984 edition was based on analyzing 10 types of vehicles (called design vehicles); the 1990 edition was based on analyzing the same 10 types and four longer semitrailers, a motor home, and a boat trailer; however, the overall height and width remained 13.5 and 8.5 feet, respectively. The design vehicles are used mainly in establishing geometrics, such as turning paths. Although a cargo tank has a very low rollover threshold, the design vehicles did not include one.

---

[43]For each vehicle, there is a lateral acceleration above which the vehicle will roll over. A vehicle's rollover threshold is related to the height of its center of gravity, its track width, and its suspension characteristics.

[44]See *Fatigue, Alcohol, Other Drugs, and Medical Factors in Fatal-to-the-Driver Heavy Truck Crashes*, Safety Study NTSB/SS-90/01.

[45]*Truck Characteristics for Use in Highway Design and Operation*, Vol. 1, Research Report, Publication No. FHWA-RD-89-226, August 1990, p. 50.

Hazardous-Materials Routing -- The New York City fire department (NYCFD) prohibits cargo tanks loaded with propane from entering or passing through the city without the NYCFD's specific authorization. The accident truck was operating under a monthly permit, number BA92/900.

The NYCFD authorization limits the number of routes that a cargo tank carrying propane can use to enter or pass through the city. The route for propane carriers from New Jersey to Nassau and Suffolk Counties in New York was the following: Tappan Zee Bridge, I-287, I-95, Throgs Neck Bridge (I-295), Clearview Expressway (I-295), to Long Island Expressway (I-595) to City Line.

In addition, the NYCFD has prohibited hazardous-materials transportation during rush hour. Propane and other hazardous materials can be transported from 10:00 a.m. to 3:00 p.m. and from 7:00 p.m. to 6:00 a.m., Monday through Friday, and all day on Saturday, Sunday, and holidays, as traffic conditions permit consistent with the rules and regulations of government agencies and/or authorities having jurisdictions.

The NYSTA operations manager indicated to Safety Board investigators that the NYSTA knew by word of mouth that hazardous-materials trucks used I-287 to avoid the NYCFD's restrictions. The NYSDOT does not establish or sign hazardous-materials routes.

I-287 Reconstruction -- This section of I-287 is scheduled to be reconstructed in 1998 as part of an 8-mile improvement. According to the NYSDOT, the design report/draft environmental impact statement was released for public comment in June 1995. The project is on the NYSDOT's 5-year capital program and is partially funded by the Federal Government.

Four alternatives are being considered: (1) rehabilitating the existing six lanes, (2) increasing the number of lanes to eight, (3) increasing the number of lanes to eight and reserving one of them for a reversible high-occupancy-vehicle (HOV) lane, and (4) doing nothing. The first three alternatives include installing highway lighting systems and a 42-inch-high single-slope concrete median barrier[46] that will divide the eastbound and westbound roadways.

National Highway System -- The Intermodal Surface Transportation Efficiency Act of 1991 authorized the NHS so as to provide an interconnected system of principal arterial routes that will serve major population centers, international border crossings, ports, airports, public transportation facilities, other intermodal transportation facilities, and other major travel

[46]This barrier qualifies as an innovative safety barrier. The NYSDOT must certify annually to the FHWA that at least 2.5 percent of new or replacement permanent median barrier used in NHS projects that receive Federal aid is innovative safety barrier. The requirement for innovative barriers is promulgated in section 1058 of the Intermodal Surface Transportation Efficiency Act of 1991.

destinations; that will meet national defense requirements; and that will serve interstate and interregional travel. According to the American Automobile Association, the proposed 159,000-mile NHS network, which includes the 47,600-mile interstate system, comprises 4 percent of the nearly 4 million miles of public roads in the United States and includes roads that carry more than 40 percent of the nation's highway traffic and about 70 percent of the heavy-truck traffic.[47]

AASHTO resolved on April 11, 1994, that "the Member Departments of AASHTO will work through AASHTO's design standards committees, with DOT, and with interested parties on design criteria and a design process for NHS routes that integrate safety..." Projects eligible for funding under the NHS include the construction, reconstruction, resurfacing, restoration, and rehabilitation, including highway safety improvements, of segments of the system.

Congress has not yet approved the NHS bill, and until the bill is enacted, approximately $6.5 billion in NHS and interstate maintenance funds is being withheld from the States.

Tests and Research

On June 27, 1995, the Safety Board held a technical review of the factual portion of this report with the parties to this investigation. On July 6, 1995, the NYSTA submitted written comments. The NYSTA said it believed that the release and "explosion" of the gas from the propane cargo tank contributed to the destruction of the column. It did not believe that the impact alone destroyed the column. It noted that on the Thruway system many bridge piers of similar size and design have been struck head-on by tractor semitrailers, but none has been damaged as the Grant Avenue overpass pier was.

The Safety Board contracted with a consultant to perform an analysis to address the NYSTA's concerns. A summary of his findings follow. (See appendix D for more details.)

The shear force at the column base would be 474 kips,[48] the shear strength of the column is 210 kips. Based on an initial truck speed of 55 mph, considering drag factors for skidding, brushing the guardrail, uprooting guardrail, and sliding on its side, the truck impacted the column at a speed of about 37 mph. At this speed, the truck possessed a kinetic energy of 3,667-foot-kips. Assuming that the tank was stopped by the rigid column, the energy was absorbed by the fluid impact pressure or force (100 kips) plus the crushing force of the truck body or tank (493 kips), or a total collision force of 593 kips. The shear force at the base of the column would be 80 percent of 593 kips, or 474 kips. The consultant further indicated

---

[47] *Safety Effects Resulting from Approval of the National Highway System*, American Automobile Association Foundation for Traffic Safety, Washington, D.C., July 1995, p. 1.

[48] A kip is a thousand pounds.

that the propane ignition did not shear off the reinforced concrete column. Gas does not have a high enough detonating velocity to do this.

Other Information

Fatigue-Related Accident Countermeasures -- When the FHWA recently coordinated a gathering of 200 experts on truck and bus safety issues,[49] the participants ranked driver fatigue as the most important of the 17 issues discussed. The need to develop and deploy emerging and practical safety technology was ranked number four. Research is underway on testing, evaluating, and developing performance specifications for drowsy-driver warning systems.

New York Task Force on Fatigue Driving -- In January 1994, the Governor of New York created the New York State Task Force on the Impact of Fatigue on Driving.[50] The task force recommended that the Governor take the following 10 steps:

1. Develop a public awareness campaign to inform motorists of fatigue as a highway risk factor and the consequences of drowsy driving, using situations that are familiar to motorists.

2. Develop an educational curriculum component on the risk and prevention of drowsy driving for integration into all appropriate driver education programs and health courses.

3. Modify the motor vehicle accident reporting form to more accurately and descriptively identify crashes related to drowsy driving.

4. Increase the installation of rumble strips on roadway shoulders.

5. Develop a training program for police officers that will increase awareness of the hazards of drowsy driving and improve the identification and reporting of drowsy driving as a factor in crashes.

6. Implement appropriate operational, managerial, design, and maintenance improvements to increase the security and adequacy of New York State's roadside rest area facilities.

---

[49]National Truck and Bus Forum, March 13-15, 1995, Kansas City, Missouri. The meeting was called by the U.S. Secretary of Transportation.

[50]*New York State Task Force on the Impact of Fatigue on Driving*, December 1994, prepared by the New York State Governor's Traffic Safety Committee and the Institute for Traffic Safety Management and Research.

7. Educate commercial drivers and their employers on the dangers and financial liability of drowsy driving and on countermeasures to reduce the occurrence of drowsy driving.

8. Identify drivers at particularly high risk for drowsy driving and develop messages and communication strategies for these target groups.

9. Conduct long-term research studies on the nature and scope of the drowsy driver problem among high-risk populations.

10. Conduct short-term and long-term research studies on the nature and scope of the drowsy driver problem among the general driving population.

The recommendations are in various stages of being implemented.

Wake Up Brochure -- The American Automobile Association Foundation for Traffic Safety has printed and distributed a brochure that is about fatigue and is aimed at truckdrivers. The Commercial Vehicle Safety Alliance, the National Private Truck Council, the American Trucking Association, and the OMC contributed to the brochure.

FHWA Studies -- The FHWA is studying several strategies for preventing fatigue-related accidents. One study is being done in conjunction with the Walter Reed Army Institute of Research to determine how long it takes a driver of a commercial vehicle to recover from fatigue. Another FHWA study, being done in conjunction with the Essex Corporation and the American Trucking Associations' Trucking Research Institute (TRI), is measuring the loss of alertness and the onset of fatigue among commercial vehicle operators. According to the FHWA, the overall intent of the studies is (1) to provide a technically sound basis for evaluating the hours-of-service regulations and (2) to develop countermeasures for reducing fatigue and increasing driver alertness. A final report on the studies, which were 5-year projects, is expected in the spring of 1996.

The OMC is currently studying whether the current public rest-area services meet the needs of commercial truckdrivers. In addition, the FHWA and the TRI are evaluating in-terminal and in-vehicle testing technologies and devices for their ability to accurately and reliably determine the fitness of commercial vehicle operators to drive their vehicles safely. The FHWA and the TRI are also undertaking a study to obtain a relatively precise estimate of the prevalence of sleep apnea[51] in a population of high-risk truckdrivers and to estimate the

[51] Sleep apnea is a sleep disorder characterized by a recurring cessation of breathing while sleeping. The resulting lack of oxygen signals the brain to wake the individual so that breathing can be restarted. This awakening is often associated with a gasp for air or a snore as breathing resumes. These interruptions often prevent deep sleep and can result in chronic sleepiness or fatigue.

level of sleep apnea at which driving impairment becomes important. In response to the Intermodal Surface Transportation Efficiency Act, the FHWA and NHTSA are cosponsoring a study of how a driver is affected in terms of stress and fatigue by operating a multiple-trailer vehicle.

Rumble Strips -- Rumble strips have been used on highways for years to warn drivers that the roadway is about to change. For instance, they are used as a warning in advance of toll booths. They are also used on the shoulder to warn drivers that they have left the roadway.

In a 1977 study, the FHWA looked at 58 accidents that involved commercial vehicles that had been struck while they were parked on highway shoulders; 47 of the 58 accidents occurred on interstate highways. A driver dozing and drifting onto a paved shoulder was the primary cause of each accident. The FHWA indicated that installing rumble strips might reduce the number of such accidents. A 1993 NCHRP Synthesis[52] indicates that rumble strips on shoulders have generally reduced the ratio of run-off-road accidents by 20 percent or more.

In 1990, the NYSTA instituted a Shoulder Treatment for Accident Reduction program.[53] Under the program, rumble strips were cut at three locations in Ulster and Erie counties. In the 30 months preceding the cutting of the strips, a total of 30 drift-off-the-road accidents had occurred at the three locations. In the 3 years after the rumble strips were installed, there were no such accidents. As a result, the NYSTA plans to install rumble strips on the entire thruway system by the year 2000.

The NYSDOT is also installing shoulder rumble strips on the New York State interstate system and on State routes. It is using its accident surveillance system to identify specific installation sites.

New Technology and Ongoing Research -- Various technologies have been developed to detect the fatigued or impaired driver, including driver readiness testing simulators, head droop, blink, and lane position monitors. In addition, a program jointly supported by the FHWA and NHTSA called IVHS-IDEA (Intelligent Vehicle Highway Systems-Innovations Deserving Exploratory Analysis) is being managed by the Transportation Research Board.

---

[52]NCHRP Synthesis 191, *Use of Rumble Strips to Enhance Safety*, A Synthesis of Highway Traffic, Transportation Research Board, National Research Council, National Academy Press, Washington, D.C., 1993, p. 20.

[53]Shafer, 1993.

One project in the program conducted by Auburn University[54] explores the feasibility of a lane control system that senses ferromagnetic or conducive paint strips through either radio frequency or infrared means. Although originally meant for use on an automated highway, a magnetic guidance system could warn a driver that he is about to leave the traffic lane. The authors of an article, *A Magnetic Lateral Guidance Concept Using Continuous Magnetic Marking,*[55] note that the system would help reduce the number of accidents that occur because a tired or sleepy driver lets his vehicle wander over the edge of the road.

Another project examines a product which will alert a driver if his vehicle is on an instrumented highway and is not in the center of the lane. The device can keep a vehicle automatically centered in the lane.[56] This project should be completed in 1995.

In the latter part of 1994, Calspan Corporation, under a subcontract from Carnegie Mellon University, was awarded part of a 5-year contract from NHTSA to find ways to prevent roadway-departure crashes. It will study the existing data on off-road crashes and propose and test potential countermeasures. The countermeasures will focus on sensors, algorithms for analyzing the data from the sensors, and human interfaces.

Activities in Other Modes -- One program in the aviation mode that has demonstrated some especially effective countermeasures regarding fatigue is the NASA Ames Fatigue Countermeasures Program. A research program, it has been underway since 1980 and has addressed strategic napping as a preventive strategy and an operational countermeasure to combat sleep loss, circadian disruption, and fatigue that occur as a result of multiple time zone changes and extended, irregular-duty schedules in flight operations.[57]

The railroad industry is also studying fatigue. A Work/Rest Review Task Force made up of representatives of the Association of American Railroads, the Brotherhood of Locomotive Engineers, and the United Transportation Union has initiated a study to examine the effects of work schedules on the performance of operating crews. The preliminary results, according to the task force, suggest that improved communications with crews about the effects of fatigue are an effective strategy.

---

[54]Hung, John Y., Ramey, G. Ed, *"Feasibility Study of IVHS Drifting Out of Lane Alert System,"* IDEA Program Final Report, Transportation Research Board, Contract Number IVHS-5, Auburn University, March 1995.

[55]Bush, E. William, Vehicle Lane Control System, IVHS-IDEA Program 12, Emerging Concepts and Products for Intelligent Transportation.

[56]Systems Progress Report I, Transportation Research Board, Washington, D.C., September 1994.

[57]Rosekind and others, 1993.

Bridge Vulnerability

Current bridge design guidelines[58] recommend that when feasible, bridge columns for freeways such as I-287 be placed 30 feet or more from the edge of the traveled way. (This area is referred to as a clear zone.[59]) Bridge columns within the 30-foot clear zone can either be protected from collision or have the damage from the collision minimized by the placement of appropriate protective devices. (Passenger cars, which typically weigh between 2,000 and 3,000 pounds, do not pose the same threat to bridge substructures as do heavy commercial vehicles, which weigh between 26,000 and 80,000 pounds.) Some high performance barriers can provide improved bridge-column protection, as well as protect heavy vehicles, such as tractor-semitrailers, from roadside obstacles.

According to the *Roadside Design Guide*, the factors most often considered in determining what the capacity of a barrier should be include whether the geometrics are adverse, whether the percentage of trucks using the roadway is high, and whether the consequences of a truck or its cargo winding up in the opposing traffic lanes are serious. The New Jersey Turnpike Authority was concerned about the latter two factors when it decided to install a 42-inch-high concrete barrier along the length of its turnpike. The NYSTA has used this barrier and other high performance barriers where it believes they are warranted.

In 1993, AASHTO adopted Load and Resistance Factor Design (LRFD) specifications[60] for new bridges. The LRFD specifications are more stringent than the *Standard Specifications for Highway Bridges* and state in Section 3.6.5.1 "Protection of Structures":

> Structures should either be protected by (1) an embankment,(2) a structurally independent, crashworthy ground-mounted 54.0-inch-high barrier, located within 10.0 feet, (3) a 42.0-inch-high barrier located at more than 10.0 feet from the component being protected," or "..abutments and piers located within a distance of 30.0 feet to the edge of roadway, or within a distance of 50 feet to the centerline of a railway track, shall be designed for an equivalent static force

---

[58] *Standard Specifications for Highway Bridges*, 15th Edition, 1992, AASHTO. The 30-foot clear zone requirement first appeared in the *Standard Specifications for Highway Bridges* in 1969. It developed from AASHTO's roadside guidelines for the protection of motorists published in 1967. See AASHO (now AASHTO) report *Highway Design and Operational Practices Related to Highway Safety*.

[59] The clear zone is a border area available for safe use by errant vehicles. The desired width is dependent upon traffic volume and speed and on the roadside geometry.

[60] Although the FHWA has not yet incorporated the LRFD into Federal regulations, in a February 10, 1994, memorandum from the Chief of the Bridge Division to the FHWA Regional Administrators, it grants: "As an interim measure...temporary approval for the use of the 1994 AASHTO LRFD bridge design specifications for Federal-aid highway project design." The FHWA expects to codify the specifications in 1995. The AASHTO subcommittee on bridges and structures will vote at its 1997 annual meeting whether to adopt the LRFD specifications exclusively in place of the *Standard Specifications for Highway Bridges*.

of 400 KIP [400,000 pounds], assumed to act in any direction in a horizontal plane, at a distance of 4.0 feet above ground.

Since 1990, the NYSDOT has been planning and developing a long-range, comprehensive bridge safety assurance program.[61] The NYSDOT is assessing the vulnerability of existing bridges to various modes of failure, including scour, earthquakes, and collisions from heavy vehicles, vessels, or trains. It is developing and implementing an overall bridge safety assurance policy for the design and construction of new bridges and for the retrofitting of existing bridges while they are being rehabilitated. Those bridges not scheduled for rehabilitation will be scheduled for remedial action that will reduce their vulnerability to collision and other failures.

The NYSDOT determined that from 1950 to 1992, 14.3 percent, or 16, of its bridge failures were due to collisions. In 1990, it surveyed bridge failures in the United States, including the District of Columbia and Puerto Rico, and received 33 responses. The survey and other sources indicated that 11.2 percent, or 121 of 1,077, bridge failures were caused by collisions.

According to an NYSDOT memo:[62]

> After the accident, the NYSDOT applied the methodology used in their safety assurance program and assessed the need for reducing the collision impact damage vulnerability of this bridge. They determined that the bridge did have a vulnerability to failure based on an extreme hit or event that might occur. Their assessment would have translated into a recommendation for installation of a high performance Jersey barrier in the area of the pier. This work would have been considered when the bridge was put on the Capital Program.

According to the NYSDOT, it has completed screening a sample of 600 to 700 (approximately 10 percent) of its bridges for vulnerability to vehicle collision. It has published an assessment manual and is developing software to allow assessment through electronic means. It hopes to complete the screening for vulnerability to vehicle collision by 1996.

Some of the NYSDOT's vulnerability-to-extreme-event assessments are further along; the program for scour, for example, is 97 percent complete. The NYSDOT's progress is not as

---

[61] Shirole, A.M., "Planning for a Comprehensive Bridge Safety Assurance Program," paper presented at the March 1991 Bridge Engineering Conference sponsored by the Transportation Research Board and the FHWA, Denver, Colorado.

[62] July 5, 1995, memorandum from M.J. Cuddy, Office of Engineering, NYSDOT, to J.A. Brunet, NYSDOT Commercial Vehicle Safety Bureau, transmitted to the Safety Board on July 19, 1995, as part of the NYSDOT's technical review of this report.

rapid as it had hoped, due to the scarcity of funds. It estimates that the full assessment for all modes of failure probably will not be finished until after the year 2000.

ANALYSIS

Introduction

This analysis will begin with a discussion of the factors and conditions that the Safety Board was able to exclude as neither causing nor contributing to this accident. The analysis will then provide a brief overview of what happened in the accident and a detailed discussion of the issues, followed by a discussion of survival factors and the emergency response.

In this accident investigation, the Safety Board identified the following safety issues:

(1) Truckdriver fatigue

(2) Carrier's oversight of the driver's work/rest cycles

(3) Countermeasures for single-vehicle roadway departures (SVRDs)

(4) Compatibility of highway design and the operating characteristics of heavy vehicles and bridge vulnerability

(5) Cargo tank integrity.

Exclusions

The road ay was clear and dry. Therefore, the Safety Board concludes that neither the weather nor the roadway surface contributed to the accident. According to the toxicological tests, the driver was not impaired by alcohol or other drugs.

Postaccident inspection of the truck revealed no identifiable preimpact mechanical deficiencies. The steering and suspension systems are the most likely components to cause a loss of control; however, the steering system and linkage were intact, and when the steering gear box was disassembled, no defects were found. A suspension spring hanger was fractured, but a metallurgical examination showed that the hanger was fractured by crash-induced overload force, rather than by precrash fatigue stresses. Although the truck broke down 39 hours before the accident because of a drive shaft problem, the drive shaft was repaired before the accident and, after the accident, was found intact with no discernible defects. Consequently, the Safety Board determines that vehicular factors did not contribute to the accident.

The Accident

To facilitate an understanding of how and why this accident occurred, the following account of the accident is presented sequentially.

Vehicle's Roadway Departure -- During the 48 hours before the accident, the driver had a maximum of 5.5 hours of sleep. Right before the accident, witnesses saw the truck "traveling at approximately 55 to 60 mph" in the middle lane (the vehicle was governed at 58 mph). One of the witnesses saw it "drift" across the left lane onto the shoulder. Although other motorists reported seeing a section of tiretread in the roadway before the accident, the Safety Board found no evidence that the truckdriver swerved to avoid an object. Rather, the tiremarks indicated that the vehicle had departed from the roadway at a shallow angle (5 degrees), which is consistent with accidents caused by impaired or fatigued drivers. In addition, the witness stated that he had not seen any brake lights or turn signals, further evidence that the driver was not trying to avoid an object in the roadway.

Vehicle Instability/Rollover -- The witness said it appeared that the left side of the truck struck the guardrail and the tractor ricocheted off the guardrail and went to the right. The tire loading marks made by the left outside semitrailer tires began at the left-lane edge line, 185 feet from the west bridge column, and arced toward the right. The maximum radius of the marks was 930 feet. (See figure 15.)

The tiremarks indicate that the truck went across the shoulder where the slope was -0.02 percent, over a 3.5-inch pavement drop, and onto the foreslope of the ditch with a slope[63] that ranged from -0.125 to -0.169 percent. Assuming that the tiremarks had a radius of 930 feet, that the percentage of slope ranged from -0.0125 to -0.169, and that the truck's rollover threshold was 0.26g, the truck rolled over at a speed of 36 to 44 mph.

Collision with Bridge Column -- That the tractor's front radiator showed no sign of impact damage and that the tank's front head bore a definite horizontal imprint of the bridge column indicate that the tank was in a rolled position when it collided with the bridge column. Safety Board investigators estimate that the tank hit the bridge with a force of 593 kips. The force of the collision stopped the tank; the fifth wheel separated; and the tractor continued east. The tiremarks east of the bridge indicate that the tractor rotated. The driver was found 260 feet east of the bridge. The tractor came to rest approximately 400 feet east of the bridge.

In the collision, the tank sheared the bridge column off. The force of the impact caused a catastrophic failure of the tank.

---

[63]Includes shoulder edge drop.

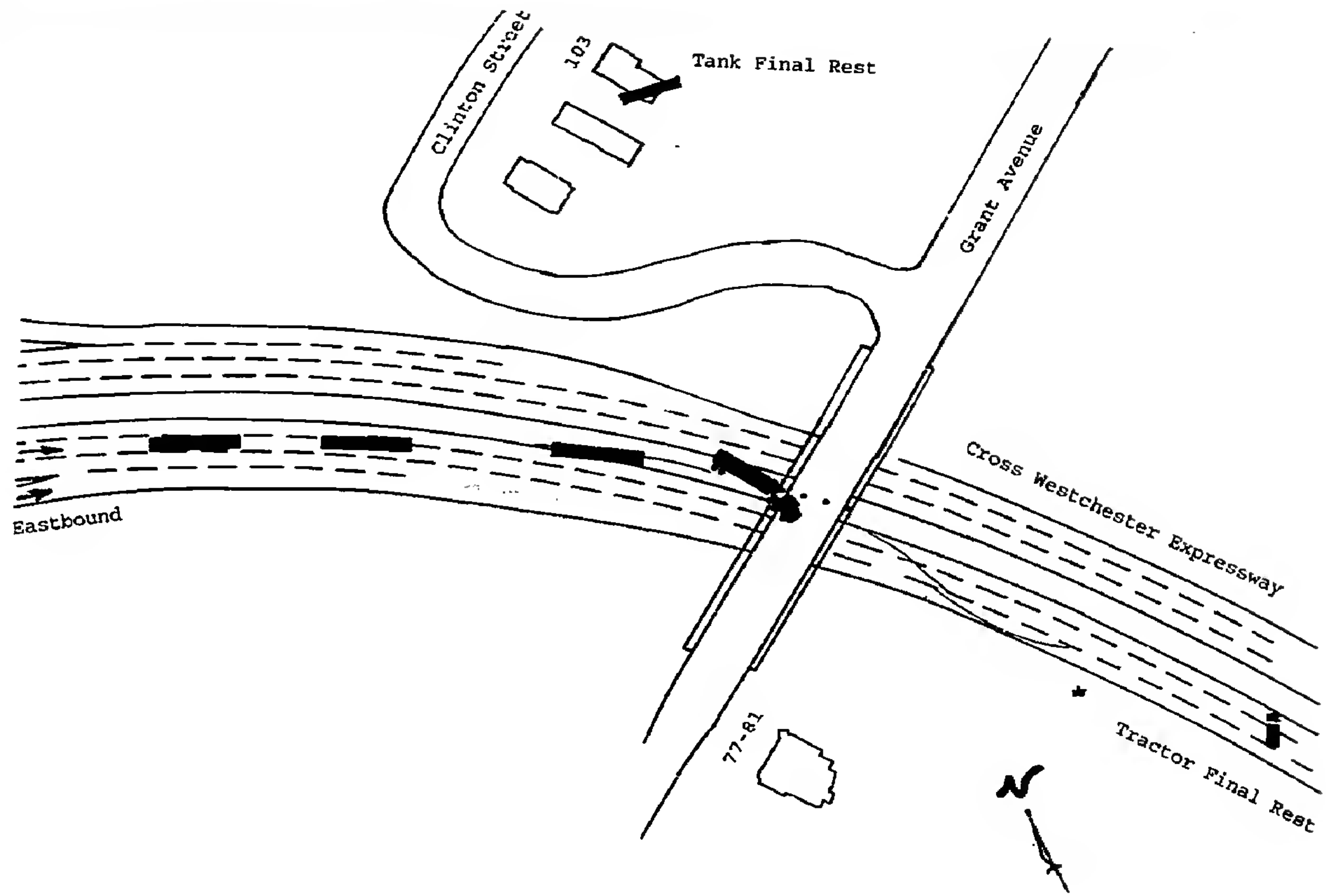


Figure 15. – Rollover sequence

Vaporization of Liquid Propane -- When the tank failed, it released liquid propane, which rapidly vaporized into gas. The resulting vapor cloud expanded until it found an ignition point. A myriad of ignition sources were available, including the truck's engine and the sparks caused by metal scraping the pavement. The Safety Board was unable to determine the source of the ignition.

Ignition and Fire -- Once the vapor cloud found a source of ignition, the gas ignited and flashed back to the fuel near the cargo tank. The tank was propelled 300 feet northward at an angle of 60 degrees with the roadway. A fractured portion of the front head of the tank separated and was propelled under the north bridge span at the west abutment backwall. The ignition of the propane gas resulted in a fireball that engulfed everything within a radius of 400 feet.

Fifth Wheel Separation -- The Safety Board determined that the damage pattern on the fifth wheel indicated that it separated from the kingpin along a horizontal plane, rather than a vertical plane, which is consistent with the pin pulling out during the rollover.

When the head of the tank collided with the bridge column, the semitrailer virtually came to a halt while the tractor's momentum was retarded by the king pin/lock jaw coupling at the fifth wheel. The Safety Board believes that the opposing forces at the fifth wheel caused the king pin to force its way through the lock jaws. The amount of force necessary to bend and distort the components of the fifth wheel could have resulted only from the opposing forces generated during the tank's impact with the bridge column. Therefore, the Safety Board concludes that the tractor and semitrailer separated when the tank hit the bridge column.

Truckdriver's Fatigue

The Safety Board conducted a detailed examination of the driver's activities during the 3 days before the accident and of his habits and sleep patterns.

He reversed his work/rest patterns every few days. He customarily drove at night for 3 days, but during the 4 days when he was off duty, he slept at night. Research has demonstrated that alertness is compromised by such disruptions in work/rest patterns[64] and that nightshifts usually tire workers more than dayshifts do.[65] Moreover, the accident occurred at 12:28 a.m.,

[64]N. McDonald, *Fatigue, Safety and the Truck Driver* (London: Taylor and Francis, 1984).

[65]D.I. Tepas and T.H. Monk, "Work Schedules," G. Salvendy, ed., *Handbook of Human Factors* (New York: Wiley-Interscience Publications, 1987).

a point in the driver's circadian cycle at which his alertness and ability to perform would be reduced.[66]

His activities during the 3 days before the accident were well documented by product invoice records and witness observations. The 10-hour breakdown disrupted his schedule and delayed his deliveries. Consequently, he had little opportunity for meaningful rest or sleep during the 2 days before the accident. An hour and a half before the accident, he told a witness that he was 10 hours behind schedule.

By his own report, the driver slept in the sleeper berth for 2 hours on the day before the accident while he was waiting for a tow truck. Later in the day, he fell asleep for half an hour while his vehicle was being repaired. He had the opportunity to sleep in the truck for up to 3 hours during the late evening/early morning hours (about 24 hours before the accident), although the Safety Board could not determine whether he actually did so. Excluding these rest periods or other undocumented brief naps, he had had no significant rest during the 48 hours before the accident.

Fragmented rest, such as that experienced by the driver in this accident, has been associated with driver fatigue and a resulting decrease in performance. Research has shown that sleep accumulated in short time blocks is less refreshing than sleep accumulated in one long time period.[67] Other research indicates that "...the more sleep is disturbed or reduced, for whatever reason, the more likely [that] an individual will inadvertently slip into sleep."[68]

The Safety Board believes that the circumstances of this accident provide clear evidence that the truckdriver's performance was affected by fatigue. The movement of the truck from the center lane, as it "drifted" across the left lane and onto the shoulder at a shallow angle without displaying turn signals or brake lights, is a classic indicator of a driver who has fallen asleep.

In addition, the driver's inverted work/rest cycle, the late hour, and his accumulation of a maximum of only 5.5 hours of fragmented sleep during the 48-hour period before the accident provide further evidence that his performance was impaired by fatigue. Therefore, the

[66]T.H. Monk and J.A. Wagner, "Social Factors Can Outweigh Biological Ones in Determining Night Shift Safety," *Human Factors*, Vol. 31, No. 6, December, 1989.

[67]Dinges, D.F., 1989, "The Nature of Sleepiness: Causes, Contexts, and Consequences," In: Stunkard, A.J.; Baum, A. *Perspectives in Behavioral Medicine: Eating, Sleeping, and Sex*, Hillsdale, NJ: Lawrence Erblaum Associates: 147-179, Chapter 9 (p. 147).

[68](a) Miller, M.; Carskadon, M.A.; Ceisler, C.A.; and others, 1988, "Catastrophes, Sleep and Public Policy: Consensus Report," *Sleep*. 11(1): 107. (b) Rosekind, M.R.; Gander, P.H.; Connell, L.J.; Co, E.L., 1994, "Crew Factors in Flight Operations X: Alertness Management in Fight Operations," NASA/FAA Technical Memorandum DOT/FAA/RD-93/1.

Safety Board concludes that at the time of the accident the driver had fallen asleep because he was suffering from acute fatigue.

Operator Fatigue in Transportation Accidents -- In every mode of transportation that the Safety Board investigates, it has found accidents in which fatigue, circadian factors, and sleep loss have been causal or contributory. The Safety Board has issued nearly 80 fatigue-related safety recommendations since 1972 to transportation operators, associations, unions, and the modal administrations in the U.S. Department of Transportation (DOT). On May 12, 1989, the Safety Board made the following three intermodal safety recommendations to the DOT:

> Expedite a coordinated research program on the effects of fatigue, sleepiness, sleep disorders, and circadian factors on transportation system safety. (Class II, Priority Action) (I-89-1)
>
> Develop and disseminate educational material for transportation industry personnel and management regarding shift work; work and rest schedules; and proper regimens of health, diet, and rest. (Class II, Priority Action) (I-89-2)
>
> Review and upgrade regulations governing hours of service for all transportation modes to assure that they are consistent and that they incorporate the results of the latest research on fatigue and sleep issues. (Class III, Longer-Term Action) (I-89-3)

In an August 11, 1989, letter, the DOT responded that coordinated research on human-factors topics, including the effects of fatigue, sleepiness, sleep disorders, and circadian rhythms on transportation, was one of its top priorities, that it would review its current policy on developing educational materials on the effects of fatigue and fatigue-related factors on transportation workers, and that, where appropriate, it was reviewing regulations governing hours of service. In an October 10, 1989, letter, the Safety Board noted that the DOT was pursuing the above, and Safety Recommendations I-89-1 through 3 were classified "Open--Acceptable."

In 1990, 1991, and 1993, the DOT briefed the Safety Board on human fatigue in transportation operations. In addition, the DOT Human Factors Coordinating Committee held a human-factors workshop on September 20-21, 1994. The workshop centered on the measurement of operator performance across transportation modes.

Truckdriver Fatigue-Related Accidents -- Since the intermodal safety recommendations were issued, the Safety Board has done two studies of heavy-truck accidents. In 1990, the Board completed a study[69] of 182 heavy-truck accidents that were fatal to the

[69]NTSB 1990.

driver. The primary purpose in investigating the accidents was to assess the role of alcohol and other drugs. The study found, however, that the most frequently cited probable cause was fatigue (31 percent).

In 1995, the Safety Board completed a study[70] based on 107 single-vehicle heavy-truck accidents. (In this analysis, that study will be referred to as the *1995 Fatigue Study*.) The purpose of the study was to examine the factors that affect fatigue. Based on a multivariate statistical analysis (a multiple discriminant analysis), the Safety Board found that the critical factors in predicting fatigue-related accidents are:

- number of hours slept in the last sleep period,
- the number of hours slept in the past 24 hours, and
- split sleep patterns.

In addition, the Safety Board concluded in the *1995 Fatigue Study* that:

- Sleep accumulated in short time blocks impedes the recovery of performance abilities.
- Driving at night with a sleep deficit is far more critical in terms of predicting fatigue-related accidents that simply nighttime driving.
- Irregular and inverted schedules can result in longer hours awake than normal and can prevent drivers from obtaining adequate sleep without careful planning.

On November 1 and 2, 1995, the Safety Board and the National Aeronautics and Space Administration's (NASA's) Ames Research Center cosponsored a multimodal symposium focusing on fatigue in transportation, how it significantly contributes to accidents, and what can be done about it. The symposium was called Managing Fatigue in Transportation: Promoting Safety and Productivity. Its purpose was to describe state-of-the art countermeasures that can be implemented now to promote safety in all modes of transportation.

Motor Carrier's Oversight of Driver's Work/Rest Cycles

The Safety Board examined why the driver continued making deliveries without proper rest, the extent of his knowledge of the adverse effects of fatigue, and the company's oversight of his hours of service.

Method of Compensation -- Paraco Gas Corporation, Inc., (PGC) allowed drivers to schedule their own work, thus requiring them to be self-disciplined enough to comply with the hours-of-service rules and to avoid becoming fatigued. The driver was confronted with a

[70] *Factors that Affect Fatigue in Heavy Truck Accidents, Volume 1: Analysis*, adopted January 18, 1995 (NTSB/SS-95/01).

difficult decision. If he rested properly (and in accordance with Federal requirements), he would be unable to complete his scheduled deliveries at his normal or expected time, thus adversely affecting his income. The flat hourly rate he would be paid for the 10-hour breakdown would not fully compensate him for not finishing his deliveries. The Safety Board concludes that he chose to sacrifice his rest in order to complete his deliveries within his normal schedule. The Safety Board also concludes that the company's policy of paying by the load instead of by the hour appeared to encourage drivers to violate hours-of-service regulations.

The Safety Board addressed the issue of method of compensation in the *1995 Fatigue Study*. The Board concluded that "the results of this study suggest a possible link between the method of driver compensation and fatigue-related accidents--an issue which has not been previously addressed in detail." The Board recommended that the Federal Highway Administration (FHWA):

> Examine truckdriver pay compensation to determine if there is any effect on hours-of-service violations, accidents, or fatigue. (Class II, Priority Action) (H-95-3)

On June 30, 1995, the FHWA responded to all the safety recommendations made to it in the *1995 Fatigue Study*. Although the response did not directly address Safety Recommendation H-95-3, the FHWA said the following:

> Because the results of research in progress and programmed for near-term initiation will significantly add to the present knowledge base on a commercial motor vehicle driver workload and alertness-reducing and alertness-enhancing measure, the FHWA will not be able to act on several of the NTSB's recommendations until after these studies are completed.

Subsequently, on August 21, 1995, the Safety Board noted:

> [the] FHWA's intention to defer action ...indicates a lack of urgency about reducing the incidence of fatigue-related accidents precipitated by truckdrivers. Because the FHWA has not acted in a timely or substantive manner on H-95-1 though -5, these recommendations are classified "Open--Unacceptable Response." The Safety Board urges the FHWA to reconsider its position and to take appropriate action.

None of the research referred to in the FHWA's June 30 letter mentioned examination of methods of compensation and the subsequent effect on safety.

After this accident, the Safety Board discussed the relationship of safety and methods of compensation with several hazardous-materials carriers. One propane carrier indicated that

because the shortage of drivers made it difficult to retain safe ones, the company was switching to paying by the hour. Another hazardous-materials carrier said that in September 1992, it had changed from paying drivers by the delivery to paying them by the hour. As a result, the company said, there had been a drastic reduction in accidents of at least 50 percent. The records of the FHWA's Office of Motor Carriers (OMC) indicate the following accident statistics for this carrier (DOT #0074278):

Table 5. -- Example of safety effects of changed method of compensation

Year	Number of Accidents
1991	18
1992	5
1993	0
1994	0

Although other factors may have been involved in reducing the company's number of accidents, the Safety Board believes the change in method of compensation had an effect. Therefore, the Safety Board reiterates Safety Recommendation H-95-3.

Education Regarding Fatigue-Producing Effects of Sleep Deficit and Irregular or Inverted Sleep Schedules -- This driver was young and healthy and may not have recognized the degree of his fatigue. A review of his records showed no evidence of his receiving any training about the effects of fatigue. The test guide for the New York State Department of Transportation (NYSDOT) commercial driver's license has a short section about fatigue, but the guide does not discuss the effects of reversed work/rest patterns and fragmented sleep. Yet the carrier's scheduling practices required the driver to monitor his own fatigue. The Safety Board concludes that he might have rested before trying to complete his last load had he been trained in understanding the effects of a deficit in sleep and irregular or inverted schedules.

The Safety Board believes that one method of reaching all new commercial truck drivers is the CDL examination. The Safety Board believes that the American Association of Motor Vehicle Administrators should review and augment the CDL manual and test materials to include information on the role of fatigue in commercial vehicle accidents and methods to identify and address fatigue.

The Safety Board addressed the adequacy of truckdrivers' understanding of the factors affecting fatigue in the *1995 Fatigue Study*. The Board found that many of the truckdrivers in the sample of drivers who had been involved in fatigue-related accidents had not recognized that they needed sleep and had believed that they were rested when they were not. About 80 percent of the drivers involved in a fatigue-related accident rated the quality of their last sleep before the accident as good or excellent. As a result of the study, the Safety Board made the following recommendation to the FHWA, the Professional Truck Driver Institute of America,

the American Trucking Associations, Inc., the Commercial Vehicle Safety Alliance, and the National Private Truck Council:

> Develop and disseminate, in consultation with the U.S. Department of Transportation Human Factors Coordinating Committee, a training and education module to inform truckdrivers of the hazards of driving while fatigued. It should include information about the need for an adequate amount of quality sleep, strategies for avoiding sleep loss, such as strategic napping, consideration of the behavioral and physiological consequences of sleepiness, and an awareness that sleep can occur suddenly and without warning to all drivers regardless of their age or experience. (Class II, Priority Action) (H-95-5)

Considering the existing body of knowledge regarding the effects of fatigue on transportation safety, the Safety Board believes that the FHWA can act on the recommendation. The American Automobile Association, with the FHWA's help, was able to assemble and disseminate a pamphlet on the adverse effects of fatigue. Therefore, the Safety Board reiterates Safety Recommendation H-95-5.

Carrier's Oversight of Hours of Service -- The Safety Board examined the time/distance relationship for the drivers assigned deliveries the week of the accident, including the 10-hour breakdown. The accident occurred 48 hours and 57 minutes after the driver began his work week. He drove for an estimated 21 hours and 12 minutes, loaded and unloaded for an estimated 9 hours and 22 minutes, was on duty for 5 hours and 20 minutes of the 10-hour breakdown,[71] totaling 35 hours and 54 minutes of on-duty time. (See appendix E for the detailed time/distance analysis.) The Safety Board found that at the time of the accident, the driver had exceeded the OMC hours-of-service rules (both the one limiting a driver to 10 hours of driving until he has had 8 hours of rest and the one limiting him to 15 hours on duty until he has had 8 hours of rest).

The new scheduling system was only 2 months old at the time of the accident, so the State and Federal governments had had little opportunity to oversee it. No level of the PGC effectively oversaw driver safety, even though the company stated that the monitoring of safety was the responsibility of three levels of management. The OMC examined the records of duty status for 80 days between May and July 1994 and found 37 false entries spanning 37 days. Some of the false entries were blatant; for example, some of the drivers had entered *off duty* in their daily logs for periods in which, in fact, they had made refinery pickups. The accident

---

[71]According to 49 *CFR* 397.5, "Attendance and Surveillance of Motor Vehicles," part (c), "A motor vehicle which contains hazardous materials other than Class A or Class B explosives and which is located on a public street or highway must be attended by its driver." The tank was empty; however, it had not been cleaned or purged and therefore had a residual load and was required to be placarded and was subject to section 397.5.

driver's personnel file did not show that the PGC had reprimanded him for log-book or hours-of-service violations.

The number of violations and the lack of evidence showing that the company took any action indicate the company was not aware of the violations, disregarded them, or sanctioned them. The Safety Board believes that with three levels of management reviewing the driver's trip documentation, someone should have detected the false log book entries. Therefore, the Safety Board concludes that the PGC's oversight of the driver's hours of service was inadequate. The Safety Board believes that the PGC should develop and implement driver scheduling, oversight, and monitoring practices that ensure that drivers obtain adequate rest and comply with Federal hours-of-service requirements.

Highway Design Countermeasures for Fatigue-Related Accidents

Preventing fatigue-related accidents is a multi-faceted problem. We can try to prevent fatigue by understanding it and being able to recognize it through education and through personal monitoring devices. We can prevent some of the causes of fatigue by regulating the number of hours a driver can work, by regulating the responsibility of the carriers, and by providing more education. We can mitigate the effects of fatigue by keeping the fatigued driver from behind the wheel and, when that fails, by changing the vehicle and the highway environment in which it operates.

The Safety Board has addressed the issue of preventing fatigue-related accidents by regulating the hours of service and by providing education in the intermodal safety recommendations and in the *1995 Fatigue Study*. The New York Task Force on the Effects of Fatigue on Driving has also addressed the prevention of fatigue-related accidents, including the use of the low-tech rumble strip. The following will address some high-tech solutions.

The Safety Board supports using new technology to reduce accidents in inclement weather by instrumenting the highway and by informing the driver of any hazardous conditions ahead. In its report of the December 1990 limited-visibility accident in Calhoun, Tennessee,[72] the Board recognized the need to monitor weather and traffic in order to prevent accidents caused by limited visibility and recommended that the DOT:

> Incorporate fog and other limited-visibility condition countermeasures in demonstration projects of the Intelligent Vehicle Highway System program (IVHS). (Class II, Priority Action) (H-92-86)

The Intelligent Vehicle Highway System is now known as the Intelligent Transportation System program, or ITS.

---

[72]See Highway Accident Report--*Multiple-Vehicle Collisions and Fire During Limited Visibility (Fog) on Interstate 75 near Calhoun, Tennessee, on December 11, 1990* (NTSB/HAR-92/02).

The DOT responded on May 24, 1993, stating that it "will support the development of IVHS products and technologies that may prove useful in both urban and rural environments. The FHWA has also approved projects for Georgia and Utah to study adverse visibility warning and control systems." On June 25, 1993, Safety Recommendation H-92-86 was classified "Open--Acceptable Response."

Recently, the Safety Board has addressed the use of crash-avoidance technology in reducing the number of rear-end collisions. About 1:50 a.m. on January 9, 1995, a multiple-vehicle rear-end collision with fire occurred during localized fog near Menifee, Arkansas.[73] The accident involved eight loaded tractor-semitrailers and a local telephone-company van. Three truckdrivers, one codriver, and the van driver were killed. The Board is scheduled to complete its report in late 1995.

As a result of the Menifee accident, the Safety Board sponsored an investigative conference entitled Mobile Collision Warning Technology for Low Visibility/Low Awareness Conditions. The conference was held on April 4 and 5, 1995, in Arlington, Virginia. Participants were invited from the transportation industry, government, and academia. They discussed technologies ranging from low-tech improvements in lighting and reflective tape to high-tech radar and laser collision warning systems.

Since many highway accidents, both fatigue-related and otherwise, also result from SVRDs, countermeasures to maintain roadway lane tracking would be valuable, especially in heavily traveled corridors used by trucks.

Mitigating the effects of fatigue-related accidents is also important. The 1994 American Association of State Highways and Transportation Officials (AASHTO) publication, *A Policy on Geometric Design of Highways and Streets*, states, "Fatigued drivers represent a sizable portion of the long-trip driving population and should be considered in freeway design." Additionally, AASHTO states:

> It is generally not possible for a design or operational procedure to reduce errors caused by innate driver deficiencies. However, designs should be as forgiving as possible to lessen the consequences of these kinds of failure. Errors committed by competent drivers can be reduced by proper design and operation. Most individuals possess the attributes and skills to drive properly and are neither drunk, drugged nor fatigued at the start of their trips. When drivers overextend

[73]See Highway Accident Report--*Multiple Vehicle Collision in Fog with Fire, Interstate 40 near Menifee, Arkansas, on January 9, 1995* (NTSB/HAR-95/03).

themselves, fail to take proper rest breaks, or drive for prolonged periods, they ultimately reach a less-than-competent state.[74]

Compatibility of Heavy Trucks and Highway Design

When the truck left the traveled way onto the negatively sloped shoulder and foreslope, its rollover speed was considerably reduced. Calculations based on a 0.26g rollover threshold show that in the center lane, which curved at a 1,522-foot radius and had a 6-percent superelevation, the rollover speed was 85 mph. On the shoulder, with a 1,542-foot radius and a minus 2-percent superelevation, the rollover speed was reduced to 74 mph. However, since the tiremarks on the shoulder and foreslope indicate steering input at a maximum radius of 930 feet, the rollover speed on the shoulder was reduced to 58 mph. Once the truck was on the foreslope, with a superelevation of -12 to -16 percent, the rollover speed was reduced even further, from 36 to 44 mph. (See appendix C for the calculations).

The highway geometry beyond the traveled way, in combination with the tight turning radius of the steering input, reduced the vehicle's rollover speed, resulting in an unstable condition. At highway speeds of 55 to 58 mph, the truck would have traveled 79 to 84 feet per second. The tiremarks left the traveled way 200 feet, or 2.5 seconds, before the truck reached the bridge. Even had there been rumble strips on the shoulder, the driver did not have enough time to perceive, react to, and avoid the hazard. Even if there had been time, once the truck lost stability, the driver could not recover. The Safety Board concludes that the truck exceeded its minimum rollover speed when it left the traveled way, at which point the vehicle lost stability and the driver was unable to recover.

Each design feature that the truck encountered, the pavement drop (3.5 inches), the slope of the ditch (-0.125 to -0.169), and the location of the guardrail, met the minimum AASHTO design guidelines in *A Policy on Geometric Design of Highways and Streets* and in the 1988 *Roadside Design Guide*. Each design feature by itself probably would not have created instability problems for the truck; but encountered together, they created a condition from which the driver could not recover. Because a passenger car has a much lower center of gravity and thus a higher rollover threshold, it probably could have negotiated these design features without stability problems; but this truck, with its high center of gravity and lower rollover threshold, could not. Therefore, the Safety Board concludes that the minimum AASHTO guidelines for the geometric design of highways are not always satisfactory for heavy trucks, especially those with high centers of gravity.

At the accident location, the guardrail was mounted on the backslope of the ditch; thus it did not prevent vehicles from transversing the ditch. According to the 1976 AASHTO

---

[74]AASHTO, *A Policy on Geometric Design of Highway and Streets*, c. 1995, Washington, D.C., p. 50.

Barrier Guide,[75] no barrier is required if the steepness of the foreslope is the only consideration. The *Barrier Guide* states that "although specific warrants for barrier protection of ditches do not exist, the designer should recognize their potential hazard. Ditches near the traveled way can be a significant hazard if their cross section[76] cannot be easily traversed by an errant vehicle." The *Guide* also indicates that a median barrier should be placed on the side of the greatest slope difference if neither slope requires protection and if the difference in the slope rate is greater than about 0.1.[77]

About 150 feet west of the column, the backslope was about 9 percent. The maximum foreslope up to 132 feet west of the column was 19 percent. The design met the AASHTO guidelines, as did the placing of the guardrail on the north side of the median.

Nevertheless, the placement of the guardrail did not reflect the best engineering practice, since it is usually better to place guardrail on the outside of curves and at the side of the ditch where the slope is greater. Additionally, since there was an upstream hazard in the westbound direction, preceded by a drainage catch basin, it would have been better to put the guardrail on the eastbound side. In this accident, the location of the guardrail was not that important because the guardrail was hit by a truck too heavy for it to redirect. Had a higher performance barrier, such as a 42-inch one, been in place nearer to the edge of the shoulder, or had the slope been relatively flat from the edge of the shoulder, the truck might have been redirected.

The purpose of placing the guardrail beyond the ditchlines might have been to give errant vehicles room to recover. Passenger cars, because of their lower centers of gravity, might have been able to recover in the ditch; however, vehicles with a high center of gravity would not.

A 1978 FHWA publication stated that "Safety priorities suggest that certain guardrail installations are more critical than others and conformance with current data is essential. As an example, guardrails on the outside of curves immediately in advance of severe hazard, or at locations where geometry may compromise barrier performance, should receive priority."[78] This guardrail was on the outside of the curve in advance of the median bridge pier (the hazard), and the slope of the roadway compromised the barrier performance.

---

[75]AASHTO, *Guide for Selecting, Locating, and Designing Traffic Barriers*, Prepared for the FHWA, Washington, D. C., 1976.

[76]The elements of a cross section include, but are not limited to, the sideslope, the right shoulder, the traveled way, the left shoulder, the median, and ditches and drainage.

[77]AASHTO, *Guide for Selecting, Locating, and Designing Traffic Barriers*, pp. 137-138.

[78]FHWA Highway Safety Review--*Report of the Safety Review Task Force to the Federal Highway Administrator*, December 1978, p. 9.

The publication also stated that "Safety upgrading ... should consider traffic volumes, barrier accident statistics, degree of deviation from current standards, potential effectiveness of existing barriers, and available resources."[79] After the accident, the NYSDOT replaced the guardrail with another guardrail of the same design. The Safety Board is concerned that the barrier on I-287 is insufficient to ensure the safety of trucks.

A heavy-truck hazardous-materials accident in an urban area can be catastrophic. Some jurisdictions have designed and constructed highways that exceed the minimum AASHTO guidelines, especially in areas where the number of trucks is high. For instance, the New Jersey Turnpike Authority uses a 42-inch-high concrete median barrier.

The Safety Board concludes that highways that are heavily traveled by trucks should be designed for them. The Safety Board believes that when I-287 is redesigned, the NYSDOT should recognize that the route is a corridor for trucks carrying hazardous materials and that the geometrics and safety appurtenances should be designed with the characteristics of heavy trucks in mind.

Highway Design Standards -- The need for highway design standards to accommodate the operating characteristics of heavy trucks has been recognized. The evolution of the improvements in compatibility is evident in the National Cooperative Highway Research Program (NCHRP) Reports 230 and 350 and in NCHRP Project 22-12.

The Safety Board agrees that heavier vehicles should be tested in accordance with NCHRP 350. The Safety Board believes that it is also important that crash-test studies include the effect of such geometric features as embankment sideslopes and ditches. The studies should include a combination of computer simulations and full-scale crash tests.

The Safety Board recognizes the need for the new performance guidelines in NCHRP Report 350 and the development of objective guidelines for the selection and installation of roadside hardware. Until NCHRP Project 22-12 is complete, designers should consider using 42-inch or 54-inch concrete barriers, which have been used successfully by many agencies, including the NYSDOT and the New York State Thruway Authority, on roads used by trucks. These barriers are already recommended in AASHTO's *Load and Resistance Factor Design* (LRFD) specifications for the protection of structures.

The Safety Board is encouraged by AASHTO's having used a greater variety of design vehicles for its 1990 and 1994 *A Policy on Geometric Design of Highways and Streets*. However, these vehicles are not being used to design safe cross sections. Because cargo tanks roll over more easily and because they often transport hazardous materials, the Safety Board

[79] See preceding footnote.

believes that they should be added to the list of design vehicles and that their characteristics, especially their rollover threshold, should be considered when designing cross sections and horizontal curves.

Previous Safety Board Recommendations Involving Heavy Vehicles and Barrier Systems -- The Safety Board has a long history of championing the need for barriers designed for heavy vehicles. In 1974, a tractor-semitrailer traveling on the New Jersey Turnpike crashed through the guardrail and crushed an automobile, resulting in 9 deaths and 11 injuries. As a result of its investigation, the Safety Board recommended that the FHWA:

> Expedite the portion of the research project, "Advanced Vehicle Protection Systems," that will provide data for the design of new barrier construction and improvements to existing systems. Dynamic impact tests should be made using both intercity buses and heavy trucks. (Class II, Priority Action) (H-75-11)

The status of the safety recommendation is "Closed--Acceptable Action".

In 1981, a cargo tank, transporting 8,300 gallons of gasoline rolled over while attempting to negotiate a 220-foot-radius right curve on a two-lane approach to a bridge in Allegheny County, Pennsylvania. It slid over a 13-inch-high concrete median barrier and into the path of an oncoming bus. Three persons were seriously injured. The Safety Board recommended that the FHWA:

> Expand the performance testing of the New Jersey shaped barrier on curved roadway sections to include crash testing of heavier vehicles with higher centers of gravity, such as 80,000-pound tractor-semitrailers and gasoline tank trucks. (Class II. Priority Action) (H-83-23)

The FHWA advised the Safety Board that a significant number of performance tests on the New Jersey shaped barriers of varying heights had been conducted and that a 42-inch-high New Jersey shaped barrier had successfully redirected an 80,000-pound tractor-semitrailer with a 64.4 inch high center of gravity at 53 mph. However, these tests were made on tangent and level roadway sections.

The Safety Board also recommended that the FHWA:

> Include the testing of heavier vehicles with higher centers of gravity in current high-performance barrier research and development. In particular, encourage the design and development of high-performance barriers that can safely contain or redirect small passenger vehicles and heavier vehicles with higher centers of gravity, such as 80,000-pound tractor-semitrailers and gasoline tank trucks. (Class II, Priority Action) (H-83-24)

The FHWA replied that a 54-inch-high bridge rail consisting of a 32-inch high New Jersey type barrier topped with a metal rail has successfully redirected an 80,000-pound tractor-semitrailer on a tangent section. A 90-inch barrier with a New Jersey type barrier profile base has successfully redirected an 80,000-pound articulated tank truck on a curved ramp and will probably successfully redirect a similar or smaller vehicle on a tangent roadway section. Safety Recommendations H-83-23 and -24 were classified "Closed--Acceptable Action" on November 19, 1985.

In 1984 the Safety Board recommended to the Texas State Department of Highways and Public Transportation:

> As part of any major pavement improvement project, provide whenever feasible for the installation of advanced barrier systems on and approaching bridges. (Class II, Priority Action) (H-84-65)

The recommendation was made as the result of an intercity bus crashing through a bridge guardrail and falling to a creek bank 26 feet below.[80] Six died and six were injured. Safety Recommendation H-84-65 was classified "Closed--Unacceptable Action" on May 23, 1989.

On September 6, 1987, an intercity bus ran off the New Jersey Garden State Parkway at a bridge, struck a guardrail, and overturned.[81] The busdriver and one passenger died. Of the remaining 33 passengers, 32 sustained minor to moderate injuries. The Safety Board recommended that the New Jersey Highway Authority:

> Replace existing steel bridge rail on the Garden State Parkway with 42-inch-high extended New Jersey safety shape bridge rail. (Class II, Priority Action) (H-88-25)

On August 29, 1989, the recommendation was classified "Closed--Unacceptable Action."

Higher performance barriers are available for redirecting heavy vehicles at highway speeds. Unfortunately, the installation of these barriers has been slow. The requirement in the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) for innovative barrier use

---

[80] See Highway Accident Report--*Trailways Lines, Inc., Bus/E.A. Holder, Inc., Truck, Rear End Collision and Bus Run-Off Bridge, U.S. Route 59, near Livingston, Texas, November 30, 1983* (NTSB/HAR-84/04).

[81] See Highway Accident Report--*Academy Lines, Inc., Intercity Bus Run-Off Roadway and Overturn, Middletown, New Jersey, September 6, 1987* (NTSB/HAR-88/03).

may speed up their use, as it has influenced NYSDOT to use a 42-inch-high concrete barrier on the reconstruction of the Cross Westchester Expressway.

The Safety Board believes that the FHWA should test heavy-vehicle impacts with barriers on curves and with cross sections that are not flat to provide additional guidance to the States so that they can better conform to the innovative barrier requirement of ISTEA. It is especially appropriate that the States have this research available as they embark on upgrading the safety features on the National Highway System (NHS).

NHS -- The roads that will be part of the proposed NHS are used by 70 percent of the heavy-truck traffic, and heavy trucks account for 78 percent of intercity freight revenue. Therefore, since trucks will be a prime user, the Safety Board believes that the NHS should be designed for the types of trucks that will travel on it, especially the portions of the NHS that run through urban areas, where accidents are more likely to have catastrophic consequences. Consequently, the Safety Board believes that the NHS should provide consistent and higher standards for trucks where the truck volumes and speeds warrant.

Changes in Truck Design -- In 1980, the Michigan legislature mandated that the University of Michigan study the configuration of cargo tanks having fluid capacities in excess of 9,000 gallons. The study[82] recommended specifications with constraints on tank capacity, tank height above the ground, rollover stability, the use of "lift-axles," and the ability of manhole covers to contain the fluid load in the event of a rollover.

The National Highway Traffic Safety Administration (NHTSA) currently has a Heavy Vehicle Aggressivity Reduction Program that involves redesigning the front-end structure of heavy vehicles to make them less destructive in truck/car collisions. The resulting geometrics should be more compatible with existing roadside hardware.

In addition, the DOT is analyzing size and weight policies for heavy vehicles. The analysis involves both NHTSA and the FHWA. The task force, which is called the Comprehensive Heavy Vehicle Size and Weight Policy Analysis, is examining both the operating and the design characteristics of heavy vehicles.

The Safety Board is pleased that the DOT is addressing these problems and encourages it to continue aggressively.

---

[82] Ervin, R.D., Mallikarjunarao, Gillespie, T.D., *Future Configuration of Tank Vehicles Hauling Flammable Liquids in Michigan*, Highway Safety Research Institute, Ann Arbor, Michigan (UM-HSRI-80-73), December 1980.

Bridge Vulnerability

The highway cross section and the design and location of the barrier system made the Grant Avenue overpass vulnerable to a heavy-truck collision. The design of the bridge, that is, the four-column pier, made the structure redundant and therefore less vulnerable to collapse.

The NYSDOT has been at the forefront in developing bridge-risk management programs, although its comprehensive bridge-safety assurance program is still under development. After the accident, the NYSDOT applied the methodology used in their comprehensive bridge safety assurance program and determined that the bridge did have a vulnerability to failure based on an extreme hit or event that might occur.

The Safety Board has addressed the topics of bridge vulnerability to collision and of bridge-risk assessment in several recent reports about its accident investigations.[83] Highway bridge vulnerability to collision from high-speed heavy vehicles was addressed in the report about the Evergreen, Alabama, accident.

In May 1993, a tractor-semitrailer that was carrying cement was traveling south on I-65 near Evergreen when it left the road, traveled along the embankment, overran a guardrail, and collided with one column of a two-column bent of an overpass. Two spans of the overpass collapsed onto the semitrailer and the southbound lanes of the interstate, sending a cloud of cement dust into the air. An automobile and a tractor-semitrailer, also southbound, then collided with the collapsed spans. The driver of the truck loaded with cement sustained serious injuries; the drivers of the other vehicles were killed.

In its report about the accident, the Safety Board concluded that the columns were vulnerable to a high-speed heavy-vehicle collision because they were within the 30-foot clear zone and had only W-beam guardrail protection. The Board noted that not all State highway departments assess bridge structures and their vulnerability to high-speed heavy-vehicle collision and subsequent collapse.

The Safety Board recommended that the FHWA :

> Request States to identify and assess bridges that are vulnerable to collapse from a high-speed heavy-vehicle collision with their bridge columns and develop and implement countermeasures to protect the structures. (Class II, Priority Action) (H-94-5)

[83] See Highway Accident Report--*Tractor-Semitrailer Collision with Bridge Columns on Interstate 65 near Evergreen, Alabama, on May 19, 1993* (NTSB/HAR-94/02); Highway-Marine Accident Report--*U.S. Towboat CHRIS Collision with the Judge William Seeber Bridge, New Orleans, Louisiana, May 28, 1993* (NTSB/HAR-94/03); and Railroad-Marine Accident Report--*Derailment of Amtrak Train No. 2 on the CSXT Big Bayou Canot Bridge Near Mobile, Alabama, September 22, 1993* (NTSB/RAR-94/01).

In cooperation with the American Association of State Highway Transportation Officials, ensure that the bridge management program guidelines include information on evaluating which bridges are vulnerable to high-speed heavy-vehicle collision and subsequent collapse. (Class II, Priority Action) (H-94-6)

On August 11, 1994, the FHWA responded to the recommendations. About Safety Recommendation H-94-6 the FHWA said, "we feel that we have provided the State highway agencies with sufficient publications to provide the recommended guidance and request that this recommendation be considered closed." In a January 12, 1995, letter, the Safety Board classified Safety Recommendation H-94-6 "Open--Acceptable Response."

In the same August letter, the FHWA said about Safety Recommendation H-94-5:

> We feel this problem can best be addressed by including it as part of our regular bridge management process. We plan to alert our field offices of the potential hazard of high-speed heavy vehicle collisions with bridge piers and to recommend they include this assessment as part of their bridge management process. . . .[the] National Bridge Inventory (NBI) includes data on bridge underclearance obstructions (e.g., piers and abutments) including the distance of the obstruction from the edge of the roadway. This data is used to determine an appraisal rating for underclearance adequacy and in calculating a sufficiency rating. Both ratings are used in setting priorities for bridge replacement and rehabilitation under the Federal bridge program.

On January 12, 1995, the Safety Board replied that it was concerned about the FHWA relying on NBI data. The Board believes that it is not possible to tell from the NBI data whether a lateral clearance measurement is based on the distance to a bridge support or on the distance to a concrete barrier. Based on the summary of responses to a bridge questionnaire about bridges that the Safety Board sent to the 50 States,[84] most States could not determine the number of columns in a pier from their inventory. Without such information, it is difficult to assess relevant site and structure characteristics. The information is also critical to measuring the vulnerability of a bridge to collision and collapse.

In its reply, the Safety Board noted that the FHWA did not agree with the Safety Board's recommendation that countermeasures be taken for any bridge that is vulnerable to collision and collapse. The Board pointed out that it had not, however, recommended that countermeasures be taken for every vulnerable bridge. Rather, the Board had asked that each bridge's vulnerability be determined and that countermeasures, if necessary, be developed as

[84]See reference in preceding footnote to Evergreen report.

part of the risk assessment of each vulnerable bridge. Because of its concerns, the Board classified, Safety Recommendation H-94-5 "Open--Acceptable Response," pending further response.

On April 28, the Safety Board received a copy of an April 12 memorandum from the Chief of the Bridge Division to the Regional Federal Highway Administrators and the Federal Lands Highway Program Administrator. (See appendix F.) The memorandum explained Safety Recommendations H-94-5 and -6 and the FHWA's position, which had not changed.

According to the memorandum, the Safety Board was advocating "a program to retrofit all existing structures that may be vulnerable or slightly vulnerable...." The Board is not advocating such a program at all. The Board believes that the States should systematically evaluate the vulnerability of their highway bridges to collision and collapse from heavy vehicles (trucks, barges, ships) and protect those that are in the most need. However, the Board believes that the FHWA should provide guidance by developing risk assessment models.

The memorandum also states, "There is not sufficient accident data on high-speed heavy-vehicle collisions with bridge piers to justify the development of separate evaluation guidelines for this type of accident." The Safety Board is aware that there may not be many high-speed heavy-vehicle collisions with bridges. However, the Safety Board is also aware that when there is such a collision, the results can be catastrophic.

After the White Plains accident, the Safety Board investigated another heavy-truck collision with a bridge column.[85] About 3:00 a.m. (local time) on August 8, 1994, a tractor-semitrailer loaded with coils of steel was westbound on I-30 near Hooks, Texas. It swerved to the left, crossed the left lane, traveled into the median parallel to the roadway behind the guardrail, and collided with the east column of a bridge. The bridge then collapsed. Two people in the truck were killed.

On July 17, 1995, the FHWA again asked that Safety Recommendations H-94-5 and -6 be closed. In discussing Safety Recommendation H-94-5, the FHWA said that it had never intended to utilize the NBI database for determining lateral clearances to bridge supports. The FHWA said:

> [it believes that] the NBI database is simply used to determine an appraisal rating for underclearance adequacy and in calculating a sufficiency rating for setting priorities for bridge replacement and rehabilitation under the Federal bridge program. The States will use existing bridge records, which includes as-built plans, in their assessment of a bridge's vulnerability to collapse from high-speed heavy-vehicle collision from supports. Bridges that are determined to be

[85]See Highway Accident Brief No. DCA-94-MH-009, June 6, 1995.

> vulnerable will have countermeasures appropriately implemented in accordance with the States' comprehensive programs to improve bridge safety and serviceability. The FHWA does agree with the appropriate implementation of countermeasures, if necessary, for vulnerable bridges as determined through a State's bridge management process.

The FHWA further indicated that "The proposed action has been taken and no additional action by the FHWA is required at this time."

The NYSDOT's assessment of the Grant Avenue bridge shows the value of a comprehensive bridge safety assurance program. Unfortunately, in this case the bridge was assessed after the accident. The Safety Board recognized the forward thinking NYSDOT comprehensive bridge safety assurance program in the New Orleans accident report. The White Plains and Hooks accidents are additional examples of what can happen when a bridge is vulnerable to collision and collapse. The Safety Board still believes that the FHWA should exercise its oversight responsibility and request that the States identify and assess the bridges that are vulnerable to collapse from a high-speed heavy-vehicle collision. Therefore, the Safety Board has reclassified Safety Recommendation H-94-5 "Open--Unacceptable Response" and reiterates the recommendation.

In the July 17 letter, the FHWA said that it had referred to Transportation Research Board Special Report 214 and the AASHTO *Roadside Design Guide* In its April 12, 1995, memorandum to the field offices. The FHWA said it believed that "more States will use the AASHTO LFRD document as they become more comfortable with the new methods presented in it." The FHWA said it planned no additional action. Since the Safety Board believes that these publications will provide the necessary guidance to the States, the Board has classified Safety Recommendation H-94-6 "Closed--Acceptable Alternative Action."

As a result of the Evergreen accident, the Safety Board also recommended that AASHTO:

> In cooperation with the Federal Highway Administration, ensure that the bridge management program guidelines include information on evaluating which bridges are vulnerable to high-speed heavy-vehicle collision and subsequent collapse. (Class II, Priority Action) (H-94-7)

The Safety Board understands that this recommendation has been forwarded to AASHTO's Highway Subcommittee on Bridges and Structures for evaluation and response. Pending the subcommittee's adoption of guidelines for the evaluation of bridges that may be vulnerable to high-speed heavy-vehicle collision and collapse, Safety Recommendation H-94-7 was classified "Open--Acceptable Response."

Risk Assessment -- Highway and railway bridge vulnerability and risk assessment for extreme events was discussed in the New Orleans and Mobile accident reports. In 1993, a towboat maneuvering in a dense fog struck and displaced the Big Bayou Canot railroad bridge near Mobile, Alabama. Shortly afterward, a train struck the displaced bridge and derailed. Forty-two passengers and five train crewmembers were killed; 103 passengers were injured.

As a result of the investigation, the Safety Board recommended that the Secretary of Transportation:

> Convene an intermodal task force that includes the Coast Guard, the Federal Railroad Administration, the Federal Highway Administration, and the U.S. Army Corps of Engineers to develop a standard methodology for determining the vulnerability of the Nation's highway and railroad bridges to collisions from marine vessels, to formulate a ranking system for identifying bridges at greatest risk, and to provide guidance on the effectiveness and appropriateness of protective measures. (Class II, Priority Action) (I-94-3)
>
> Require that the Federal Railroad Administration and the Federal Highway Administration, for their respective modes, use the methodology developed by the intermodal task force to carry out a national risk assessment program for the Nation's railroad and highway bridges. (Class II, Priority Action) (I-94-4)

In a February 2, 1995, letter the Secretary of Transportation indicated that the task force had been formed and had adopted the basic risk assessment methodology described in the 1983 National Research Council study *Ship Collisions with Bridges, The Nature of the Accidents, Their Prevention and Mitigation.*[86] The Safety Board responded on April 24, 1995, that it was pleased with the task force's progress and had classified Safety Recommendations I-94-3 and -4 "Open--Acceptable Response."

Cargo Tank Integrity

The Safety Board has previously addressed its concerns about a cargo tank full of compressed gases failing catastrophically in an accident. In 1975, the Safety Board investigated a highway accident in Eagle Pass, Texas,[87] which involved the catastrophic failure of a tank carrying 8,748 gallons of LPG. The tank separated from the tractor, struck a concrete head wall, and ruptured, releasing the LPG. Fifty one people were burned in the ensuing fire; and of the 51, 16 died.

---

[86]National Academy Press, Washington, D.C., 1983.

[87]See Highway Accident Report-*Surtigas, S.A., Tank-Semitrailer Overturn, Explosion, and Fire, near Eagle Pass, Texas, April 29, 1975* (NTSB-HAR-76-4).

As a result of its investigation, the Safety Board recommended that the DOT:

> Initiate a research program to identify new approaches to reduce the injuries and damages caused by the dangerous behavior of pressurized, liquefied flammable gases released from breached tanks on bulk transport vehicles. (I-76-5)

In 1978, the Research and Special Programs Administration (RSPA) contracted for research[88] in this area, and the Board classified the recommendation "Closed--Acceptable Action."

In 1979, after a railroad derailment in Crestview, Florida,[89] that resulted in the failure of several rail tank cars carrying liquefied compressed gases, the Safety Board recommended that RSPA:

> Expand current research into 'new approaches for controlling pressurized liquefied flammable gas releases' from breached tanks on bulk transport vehicles to include control of pressurized liquefied nonflammable ammonia and chlorine gas releases. (I-79-12)

In 1991, RSPA advised the Safety Board that the research program to find new approaches for controlling pressurized gas releases had been canceled several years earlier. RSPA noted that the research had not yielded any viable alternatives to railroad shelf-couplers, headshields, and thermal protection, all of which had proven effective in preventing product release. RSPA also noted that further research was not justified and requested that the recommendation be classified "Closed--Acceptable Alternative Action."

In an April 3, 1992, letter to RSPA, the Safety Board agreed that shelf-couplers, headshields, and thermal protection had dramatically improved safety when installed on rail tank cars and had reduced the number of catastrophic failures of pressurized tank cars. However, the Safety Board reminded RSPA, Safety Recommendation I-79-12 was an intermodal recommendation. The Board noted that RSPA had not addressed new approaches for controlling pressurized gas releases from breached highway cargo tanks. To further support the recommended research, the Safety Board told RSPA about the following highway accident investigations that involved the failure of cargo tanks carrying LPG.

---

[88] Contract DOT-RC-82039, September 26, 1978.

[89] See Railroad Accident Report--*Louisville & Nashville Railroad Company Freight Train Derailment and Puncture of Hazardous Materials Tank Cars, Crestview, Florida, April 8, 1979* (NTSB-RAR-79/11).

Table 6. -- Accident investigations involving liquefied petroleum gas

Date	Location	Burn Injuries	Fatal Burn Injuries
April 29, 1975	Eagle Pass, Texas	51	16
April 6, 1987	Lawrenceville, New Jersey	7	0
December 23, 1988	Memphis, Tennessee	23	9
January 20, 1992	Crawford, Mississippi	4	3

In the Lawrenceville and Memphis accidents, the front heads of the cargo tanks failed after they struck bridge structures. In the Crawford accident, the front head failed after it struck another vehicle.

In the April 3 letter, the Safety Board again urged RSPA to do the recommended research. RSPA did not respond. Since there was no indication that RSPA had taken action to conduct the recommended research, on June 29, 1994, the Safety Board classified Safety Recommendation I-79-12 "Closed--Unacceptable Action."

On February 4, 1992, the Safety Board adopted a special investigation report on cargo tank rollover protection.[90] The report addressed the need to evaluate the forces that act on cargo tanks during rollover accidents and the need to establish performance standards for rollover protection devices based on analysis of those forces. As part of the special investigation, the Safety Board found that NASA had used computer analysis to improve the crashworthiness of cargo tanks used to transport rocket fuels. Special design features were incorporated into the cargo tank configuration to protect the tank in the following kinds of impact: a 55-mph frontal collision with an unyielding surface; a 55-mph lateral impact from another tractor-trailer weighing 80,000 pounds; and a rollover and 18-foot fall from an overpass.

The accident in White Plains again demonstrates the destructive potential of a cargo tank carrying flammable compressed gases when it catastrophically fails during a highway accident. The Safety Board is concerned about the adequacy of minimum construction requirements that allow a front tank head to be 33 percent thinner than the tank barrel. In rollover or jackknife accidents, the front head is vulnerable to collision with fixed objects. Therefore, the Safety Board concludes that the front head on a cargo tank is vulnerable to being damaged and subsequently releasing the cargo.

The Safety Board has previously recognized the effectiveness of headshields in reducing tank head punctures in train derailments and the efforts of NASA to design a front head impact limiting system for highway cargo tanks it uses to transport rocket fuels. The Safety Board could not determine whether it is reasonable to design tank heads that could have withstood the

[90]See Hazardous Materials Special Investigation Report, *Cargo Tank Rollover Protection*, February 4, 1992, (NTSB/SIR-92/01).

impact forces involved in this accident. The Safety Board believes that the FHWA and RSPA should research methods and develop standards to improve the crashworthiness of front heads on cargo tanks used to transport liquefied flammable gases and potentially lethal nonflammable compressed gases.

Survival Factors and Emergency Response

Collision -- The driver was found face down on the pavement. The back of his body was burned, but not the front. He died of severe blunt trauma injuries. There were no loading marks on the front of his body from the seatbelt. Therefore, the Safety Board concludes that the driver was not wearing the available restraint system.

The driver would not have been ejected had he worn the restraint system. Since there was no evidence of intrusion into the cab, there was survivable space. However, since the cab was consumed by fire, the Safety Board was unable to determine whether the use of the restraint system would have saved his life.

The Safety Board's review of the PGC's policies and practices regarding seatbelt use indicated that the company did not have a specific written requirement that seatbelts be used. The Safety Board believes that the company should institute a written policy to ensure that all of its drivers comply with the Federal Regulations (49 *CFR* 16) requiring the use of seatbelts whenever the vehicle is in motion, should ensure that all drivers are made aware of this requirement, and should ensure that seatbelt use is periodically monitored.

Fire -- The 19 injured residents were injured escaping burning buildings. The four firefighters with minor injures were injured fighting the fires. The emergency response forces reacted promptly and with appropriate strength. All injured people were treated and evacuated from the scene within a reasonable time. White Plains had developed an ongoing training program for emergency responders. Its performance in this accident indicates that the training program is effective. The Safety Board concludes that the emergency response of White Plains and its neighboring jurisdictions was effective.

CONCLUSIONS

1. Neither the weather nor the highway surfacc contributed to the accident; the driver was not impaired by alcohol or other drugs; and the truck had no apparent preimpact mechanical deficiencics.

2. The tractor and semitrailer separated when the tank hit the bridge column.

3. The driver chose to sacrifice his rest in order to complete his deliveries within his normal schedule. At the time of the accident, he had probably fallen asleep because he was suffering from acute fatigue.

4. The carrier's policy of paying by the load instead of by the hour appeared to encourage drivers to violatc hours-of-service regulations.

5. The driver might have restcd before trying to complctc his last load had he been trained in understanding the effects of a deficit in sleep and irregular or inverted rcst schedules.

6. The carrier's oversight of thc drivcr's hours of service was inadequate.

7. The truck exceeded its minimum rollover speed when it lcft the roadway, at which point the vchiele lost stability and the driver was unable to recover.

8. The minimum guidclincs sct by the American Association of State Highway and Transportation Officials for the geometric design of highways arc not always satisfactory for heavy trucks, espceially those with high centers of gravity.

9. Highways that are heavily traveled by trucks should also be designed for truck operating characteristics.

10. The front hcad on a cargo tank is vulnerable to being damaged and subsequently rclcasing thc cargo.

12. The driver was not wearing the available restraint system.

13. The cmergcncy rcsponse of White Plains and its neighboring jurisdictions was effcctivc.

PROBABLE CAUSE

The National Transportation Safety Board determines that the probable causes of this accident were the reduction in the alertness of the driver (consistent with falling asleep) caused by his failure to properly schedule and obtain rest, and the failure of the management of Paraco Gas Corporation, Inc., to exercise adequate oversight of its driver's hours of service. Contributing to the accident was the design of the highway geometrics and appurtenances, which did not accommodate an errant heavy vehicle. Contributing to the severity of the accident was the vulnerability of the bridge to collision from high-speed heavy vehicles.

RECOMMENDATIONS

As a result of its investigation of this accident, the National Transportation Safety Board makes the following recommendations:

--to the Federal Highway Administration:

> Require that highway geometric design and traffic operations of the National Highway System be based on heavy-truck operating characteristics. (Class II, Priority Action) (H-95-32)
>
> Conduct research with cargo tanks (80,000 pounds) to evaluate the safety performance of roadside barriers and highway geometrics, such as embankment sideslopes and ditches, and change the standards accordingly. (Class II, Priority Action) (H-95-33)
>
> Require any Federal-aid project involving bridges to use the 1994 Load and *Resistance Factor Design* guidelines for the protection of structures and the design of piers. (Class II, Priority Action) (H-95-34)
>
> Cooperate with the Research and Special Programs Administration in studying methods and developing standards to improve the crashworthiness of front heads on cargo tanks used to transport liquefied flammable gases and potentially lethal nonflammable compressed gases. (Class II, Priority Action) (H-95-35)
>
> Cooperate with the American Association of Motor Vehicle Administrators and the American Trucking Association to review and augment the commercial drivers license manual and test materials to include information on the role of fatigue in commercial vehicle accidents and methods to identify and address fatigue. (Class II, Priority Action) (H-95-36)

--to the Research and Special Programs Administration:

> In cooperation with the Federal Highway Administration, study methods and develop standards to improve the crashworthiness of front heads on cargo tanks used to transport liquefied flammable gases and potentially lethal nonflammable compressed gases. (Class II, Priority Action) (H-95-37)

--to the New York State Department of Transportation:

When Interstate 287 is redesigned, design the geometrics and safety appurtenances for the vehicle characteristics of heavy trucks. (Class II, Priority Action) (H-95-38)

--to the American Association of State Highway and Transportation Officials:

Add a cargo tank to the design vehicles in the AASHTO A Policy on Geometric Design of Highways and Streets. (Class II, Priority Action) (H-95-39)

--to the American Association of Motor Vehicle Administrators:

In cooperation with the Federal Highway Administration and the American Trucking Association review and augment the commercial drivers license manual and test materials to include information on the role of fatigue in commercial vehicle accidents and methods to identify and address fatigue. (Class II, Priority Action) (H-95-40)

--to the American Trucking Association:

Cooperate with the American Association of Motor Vehicle Administrators and the Federal Highway Administration to review and augment the commercial drivers license manual and test materials to include information on the role of fatigue in commercial vehicle accidents and methods to identify and address fatigue. (Class II, Priority Action) (H-95-41)

--to Paraco Gas Corporation, Inc.:

Develop and implement driver scheduling, oversight, and monitoring practices that ensure that drivers obtain adequate rest in accordance with Federal hours-of-service requirements. (Class II, Priority Action) (H-95-42)

(a) Institute a written policy to ensure that all company drivers comply with the Federal Regulations (49 *CFR* 16) requiring the use of seatbelts whenever the vehicle is in motion; (b) ensure that all drivers are made aware of this

requirement: and (c) monitor seatbelt use periodically. (Class II, Priority Action) (H-95-43)

Also, the National Transportation Safety Board reiterates the following safety recommendations to the Federal Highway Administration:

H-94-5

Request States to identify and assess bridges that are vulnerable to collapse from a high-speed heavy-vehicle collision with their bridge columns and develop and implement countermeasures to protect the structures.

H-95-3

Examine truckdriver pay compensation to determine if there is any effect on hours-of-service violations, accidents, or fatigue.

H-95-5

Develop and disseminate, in consultation with the U.S. Department of Transportation Human Factors Coordinating Committee, a training and education module to inform truckdrivers of the hazards of driving while fatigued. It should include information about the need for an adequate amount of quality sleep, strategies for avoiding sleep loss, such as strategic napping, consideration of the behavioral and physiological consequences of sleepiness, and an awareness that sleep can occur suddenly and without warning to all drivers regardless of their age or experience.

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

JAMES E. HALL
Chairman

ROBERT T. FRANCIS II
Vice Chairman

JOHN A. HAMMERSCHMIDT
Member

JOHN J. GOGLIA
Member

November 14, 1995

APPENDIX A

INVESTIGATION

The National Transportation Safety Board was notified of this accident at 6:20 a.m. on July 27, 1994, by the New York State Police.

Accident investigators dispatched from the Safety Board's Parsipany, New Jersey, regional office arrived on scene at 10:00 a.m., and investigators dispatched from the Safety Board's headquarters office in Washington, D.C., arrived on scene at 12:00 noon, July 27, 1994.

Participating in the investigation were representatives of Paraco Gas Corporation, Holland Hitch, Trinity Industries, Ryder Truck Rental, the White Plains Fire Department, the New York State Thruway Authority, the New York Sate Department of Transportation, the New York State Police, and the Federal Highway Administration.

Hearing/Deposition

The Safety Board did not hold a public hearing or deposition proceedings in connection with this accident. The Safety Board obtained sworn testimony from several witnesses and Paraco employees.

APPENDIX B

INJURY INFORMATION

Injuries in this accident have been coded to the revised 1990 Abbreviated Injury Scale of the American Association for Automotive Medicine, which is the standard system of assessing injury severity.

Abbreviated injury scale table

Injuries	Truck Driver	Residents	Fireman	Total
AIS-1 Minor		9	4	13
AIS-2 Moderate		4	0	4
AIS-3 Serious		4	0	4
AIS-4 Severe		0	0	0
AIS-5 Critical		2	0	2
AIS-6 Unsurvivable	1	0	0	1
AIS-0 None		0	0	0
AIS-9 Unknown		0	0	0
Total	1	19	4	24

APPENDIX C

ROLLOVER SPEED CALCULATIONS

Calculations for the speed of the cargo tank combination unit at its loss of stability and rollover are performed using the following formula:

$$V = RG\ ((w/h) + e)^{1/2}$$

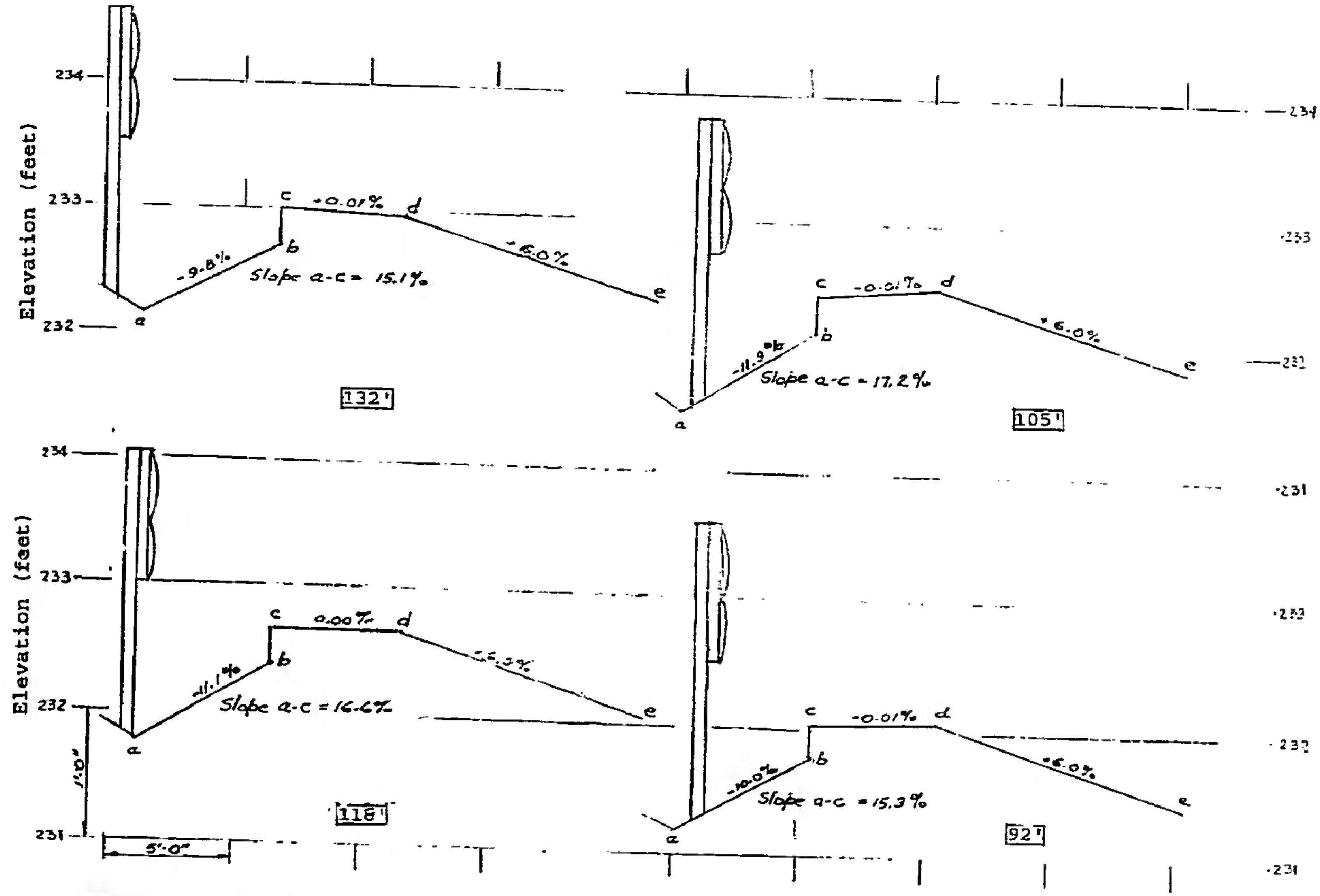
where V= velocity in feet per second, R= radius of the path of the cargo tank's center of mass, G= acceleration of gravity or 32.2 feet per second squared, w/h= the rollover threshold (1/2 of the track width divided by the height of the center of mass), and e= the superelevation of the roadway. The following tabulation indicates a range of calculated rollover speeds (converted to speeds in miles per hour, mph, from velocity in feet per second, fps).

Location	Radius in Feet	Superelevation	Rollover Threshold	Rollover Speed in mph
Without Steering Input				
Shoulder	1542	-0.02	0.26	74
Foreslope	1547	-0.125 to -0.169	0.26	46 to 56
With Steering Input				
Shoulder	930	-0.02	0.26	58
Foreslope	930	-0.125 to -0.169	0.26	36 to 44

Rollover Speeds

The following four diagrams show the derivation of the superelevation at four different locations on the roadway prior to the accident site. The elevations were determined from the survey made after the accident by CHAS H. SELLS, INC., of Bedford Hills, New York.

APPENDIX C – Continued



ab = ditch slope
bc = shoulder drop off
cd = shoulder
de = traveled way

[000] Distance West of Impacted Column

Scale
Vertical: 1" = 1'-0"
Horizontal: 1" = 5'-0"

PARTIAL CROSS SECTION of EASTBOUND I-287 TRAVELED WAY & MEDIAN WEST of GRANT AVE. BRIDGE

APPENDIX D

SUMMARY OF CONSULTANT'S FINDINGS

The following is a summary of the tasks of the contract[1] with the answers and discussion:

1. Did the sheared column meet the design criteria in the 1953 AASHO (AASHTO) specifications in effect at the time the bridge was designed (1956)?

The column apparently met the 1953 AASHO design criteria. The consultant used the minimum allowable concrete compressive strength of 3,000 psi and a minimum yield strength of 40,000 psi. The maximum design axial load was 1,123 kips; the maximum allowable shear load was 110 kips. A simplified static analysis indicated that the shear force at the bottom of the column would be about 80 percent of a horizontal force applied 3.5 feet from the bottom of the column.

2. Did the column meet the most recent AASHTO bridge specifications?

The column would probably not meet 1989 AASHTO bridge specifications. This bridge is in a seismic zone, and bridges designed since 1981 must meet strength requirements to resist horizontal earthquake forces. The shear strength of the column was computed to be about 210 kips.

3. Did the column satisfy Section 3.6.5.3 in the 1994 AASHTO LRFD Bridge Design Specifications?

No. The column could resist a 262-kip force applied 3.5 to 4 feet above the ground. This is less than the LRFD bridge design specifications requirement of 400 kips in a horizontal plane at a distance of 4 feet above the ground for a column within 30 feet from the roadway (edge of traveled way).

4. Would the impact force alone have destroyed the column?

Yes. The shear force at the column base would be 474 kips; the shear strength of the column is 210 kips.

---

[1] Hirsch, T.J., "LPG SEMI-TRAILER TANK TRUCK COLLISION WITH BRIDGE COLUMN," College Station, Texas, September 7, 1995.

A reconstruction of the accident based on an initial truck speed of 55 mph, considering drag factors for skidding, brushing the guardrail, uprooting guardrail and sliding on its side, indicated that the truck impacted the column at a speed of about 37 mph. At this speed, the truck possessed a kinetic energy of 3,667 ft-kips. Assuming that the tank was stopped by the rigid column, the energy was absorbed by the fluid impact pressure or force (100 kips) plus the crushing force of the truck body or tank (493 kips), or a total collision force of 593 kips. The shear force at the base of the column would be 80 percent of 593 kips, or 474 kips.

The liquid propane gas ignition did not shear off the reinforced concrete column. Gas does not have a high enough detonating velocity to do this.

5. If a 32-inch high New Jersey borrier hád been installed at the same location as the W-beam guardrail, would it hove successfully redirected the vehicle and/or prevented the destruction of the column?

Published test results[2] (on level pavement [cross section]) and real accident conditions indicate that loaded tractor-trailers (vans and cargo tankers) traveling at 50 mph (and above) and impacting at 15 degrees (or more) will mount and fall over a 32-inch New Jersey barrier. This semi-trailer tanker impacting a similar barrier could not be expected to perform any better because of its higher center of gravity and the adverse highway geometrics (10 percent ditch slope and shoulder drop off), albeit the smaller impact angle. The column would almost surely have been destroyed.

6. If a 32-inch-high New Jersey barrier had been locoted at the edge of shoulder, would the vehicle have been redirected and/or prevented the destruction of the column?

The barrier would have had a better chance at redirecting this vehicle, but the results would likely have been similar.

7. Would a 42-inch-high single slope barrier have redirected the vehicle at either the existing guardrail location or at edge of shoulder?

A single-unit 18,000-pound truck at 50 mph and a 15-degree impact angle is the largest vehicle crash tested with a single slope barrier. However, a 42-inch-high New Jersey barrier was successfully tested with an 80,180-pound tractor trailer van at 52 mph and 15 degrees. The performance of the single sloped barrier is equal to or exceeds the New Jersey barrier. Two other 42-inch-high concrete shapes (but not the single slope barrier) were successfully tested with 50,000-pound tractor-trailer vans at angles around 15 degrees and 50 mph speeds.

---

[2] *Symposium on Geometric Design for Large Trucks, Transportation Research Record 1052*, Transportation Research Board, Washington, D.C., 1986.

The consultant believes that this LPG tractor-trailer tanker would have been redirected by a 42-inch-high concrete barrier, located at the edge of shoulder. However, the short distance from the edge of shoulder to the column would have placed the barrier face about 3.25 feet from the face of the column, and it is possible that the truck's roll would have been sufficient for the truck to impact the column but probably not destroy it. The 1994 AASHTO LRFD bridge design specifications recommend a minimum clear distance of 10 feet between a column and roadway for 42-inch-high barriers.

8. Would a 54-inch-high barrier, the specified barrier in the LRFD specifications for clearances of less than 10 feet between the roadway and the column, have redirected this vehicle and/or prevented the impact with the column?

In this accident, the truck would have impacted the barrier at 50 mph and at an angle of 6 degrees, 115 feet upstream from the column. The 54-inch-high barrier would have restrained and redirected the truck. Both the 42-inch-high and 54-inch-high barriers should perform equally as well because only the 42-inch diameter tires would have contacted the barrier. For impacts with trucks with center of gravities in the 70 to 74-inch range at angles of 15 degrees, and 50 mph speeds, a 90-inch-high barrier is recommended to prevent possible roll into columns which are close to the roadway.

APPENDIX E

TIME/DISTANCE ANALYSIS

No.	Trip	Clock Time*	Drive Time	Load/Unload Time	On-Duty Time	Off-Duty Time	Trip Distance[1]	Avg. Speed*	Tank Status
	Monday, July 25								
1	Smithtown, NY to Linden, NJ	2330 0130	2:00				79	39	E
	(Loading)			0:30	2:30				
2	Linden, NJ to Mt. Vernon, NY	0200 0330	1:30				78	52	F
	(Unloading)			1:00	2:30				
3	Mt. Vernon, NY to Linden, NY	0430 0531	1:01				33	33	E
	(Loading)			0:21	1:22				
4	Linden, NJ to Peckskill, NY	0552 0715	1:23				73	52	F
	(Unloading)			1:00	2:23				
5	Peekskill, NY to Breakdown on I-287	0815 0900	0:45		0:45		23	31	E
	Waiting on I-287	0900 1300			4:00[2]				
	Towed from I-287 to Yonkers	1300 1420			1:20				
	Repair	1420 1915				4:55[3]			
6	Yonkers, NY to Port Reading, NJ	1915 2040	1:25				37	27	E

[1]The distances were derived from the Household Goods Carriers' Bureau, Mile Guide No. 16, Volume Two.

[2]Title 49 CFR 397.5, Attendance and Surveillance of Motor Vehicles, part (c), states that "A motor vehicle which contains hazardous materials other than Class A or Class B explosives and which is located on a public street or highway must be attended by its driver." The cargo tank was empty; however, it had not been cleaned or purged and therefore had a residual load that required it to be placarded and that rendered it subject to 397.5.

[3]According to 49 CFR Part 395-Hours of Service of Drivers, he cannot claim this time as off duty because there is not a minimum 2-hour period in the sleeper berth. Witness statements indicate that he consumed a sandwich from 1430-1530 and that he napped in the Ryder van from 1645-1715.

No.	Trip	Clock Time*	Drive Time	Load/Unload Time	On-Duty Time	Off-Duty Time	Trip Distance[1]	Avg. Speed*	Tank Status
	(Loading)			0:30	1:55	0:18			
7	Port Reading, NJ to Stratford, CT	2128 [23:30]	[2:02]				112	[55]	F
	(Unloading)			1:00	[3:02]	[3:16]			
	Tuesday, July 26								
8	Stratford, CT to Linden, NJ	[03:46] 0454	[1:08]				62	[55]	E
	(Loading)			0:31	1:39				
9	Linden, NJ to Peekskill, NY	0525 [0645]	[1:20]				73	[55]	F
	(Unloading)			1:00	2:20	0:44			
10	Peekskill, NY to Port Reading , NJ	[08:29] 0944	[1:15]				69	[55]	E
	(Loading)			0:30	1:45	0:49			
11	Port Reading, NJ Peekskill, NY	1103 1300	1:57				78	40	F
	(Unloading)			1:00	2:57	0:40			
12	Peekskill, NY to Port Reading, NJ	[14:40] 1555	[1:15]				69	[55]	E
	(Loading)			0:30	1:45	0:42			
13	Port Reading, NJ to Mt. Vernon, NY	1707 1940	2:33				83	33	F
	(Unloading)			1:00	3:33	0:23[4]			
14	Mt. Vernon, NY to Port Reading, NJ	[21:03] 2144	[0:41]				38	[55]	E
	(Loading)			0:30	1:11	0:39			
15	Port Reading,NJ to accident on I-287	2253 0027	1:34				69	46	F
	Totals (hrs:min)	48:57	21:12	9:22	35:34				

*Bracketed figures are estimates

[4]Witness statement places the driver at a fast food restaurant at 2035.

APPENDIX F
FHWA APRIL 12 MEMO TO REGIONAL FEDERAL HIGHWAY ADMINISTRATORS

U.S. Department of Transportation
Federal Highway Administration

Memorandum

Subject: **ACTION**: NTSB Sefaty Recommendations

Date: APR 12 1995

From: Chief, Bridge Division
Office of Engineering

Reply to Attn. of: HNG-33

To: Regional Federal Highway Administrators
Federal Lends Highway Program Administrator

The National Transportation Sefaty Board (NTSB) conducted an investigation of a bridge collapse occurring on Interstate 65 near Evergreen, Alebama on May 19, 1993, that was caused by a truck collision with one column of a two-column bridge pier. The collision ceused two spans of the bridge to fall onto the roadway below and resulted in two fetelities.

As a result of this incidant, the NTSB made the following recommandations for action by the FHWA:

1. Request States to identify and assess bridges that are vulnerable to collapse from a high-speed heavy-vehicle collision with their bridge columns and develop and implement countermeasures to protect the structures.

2. In cooperation with the American Association of State Highway and Transportation Officials (AASHTO), ensure that the bridge management program guidelines include information on evaluating which bridges are vulnerable to high-speed heavy-vehicle collision and subsequent collapse.

We share the NTSB's concern for the potentially serious consequences as a result of high-speed heavy-vehicle collisions with bridge columns. However a program to retrofit all existing structures that may be vulnerable, or slightly vulnerable, to high-speed heavy-vehicle collisions with bridge piers should not be undertaken at the expense of other safety programs that may be more effective and efficient in terms of reducing accidents. Rather, the actions should be evaluated as a part of a comprehensive program to improve bridge safety and serviceability.

With respect to the second recommendation, we believe that States have the essential information and experience to determine bridge vulnerability to high-speed heavy-vehicle collisions and to design countermeasures. Existing publications such as the Transportation Research Board Special Report 214, Designing Safer Roads, Practices for Resurfacing, Restoration, and Rehabilitation provide guidence and methodologies for estimating the frequency of roadside encroachments and for design of countermeasures. Additional guidence is also included in AASHTO's Roadside Design Guide. There is not

sufficient accident data on high-speed heavy-vehicle collisions with bridge piers to justify the development of separate evaluation guidelines for this type of accident.

In response to the above NTSB recommendations, please request the Divisions to alert the States of the potential hazard of high-speed heavy-vehicle collisions with bridge piers and request that they assess the hazard of such accidents site by site using available guidance. The priority of mitigative actions may then be determined by each State through their bridge management process.

Stanley Gordon